U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 133.

A. C. TRUE, DIRECTOR.

REPORT

OF

IRRIGATION INVESTIGATIONS FOR 1902,

UNDER THE DIRECTION OF

ELWOOD MEAD,

CHIEF OF IRRIGATION INVESTIGATIONS.

CONTAINING REPORTS BY

F. R. MORGAN, J. D. STANNARD, B. P. FLEMING, O. L. WALLER, S. FORTIER,
W. T. CLARKE AND C. W. LANDIS, A. B. CRANE, FRANK BOND,
J. C. NAGLE, H. J. WATERS, A. R. WHITSON, E. B.
VOORHEES, AND JARED SMITH.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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WASATCH MOUNTAINS.

U. S. DEPARTMENT OF AGRICULTURE.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

OFFICE OF EXPERIMENT STATIONS.

A. C. True, Ph. D., *Director.*
E. W. Allen, Ph. D., *Assistant Director.*

IRRIGATION INVESTIGATIONS.

Elwood Mead, *Chief.*
C. T. Johnston, *Assistant Chief in Charge Central District.*
Samuel Fortier, *Irrigation Engineer in Charge Pacific District.*
C. G. Elliott, *Agent and Expert in Charge of Drainage Investigations.*
R. P. Teele, *Editorial Assistant.*
C. E. Tait, *Assistant in Charge of Maps and Illustrations.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 25, 1903.

Sir: I have the honor to transmit herewith a report of the irrigation investigations carried on by this Office during the season of 1902, under the direction of Prof. Elwood Mead, chief of irrigation investigations, and to recommend its publication as a bulletin of this Office. It gives the result of another season's investigations of the problems of irrigation which have been carried on along similar lines for four years past, the results obtained in previous years being reported in Bulletins 86, 104, and 119 of this Office. The increasing demand for information on the subjects dealt with shows that their value in the development of the West is being more and more recognized.

The illustrations, which comprise twelve full-page plates and sixteen text figures, are an essential part of the report.

Respectfully, A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 30, 1903.

Sir: I have the honor to submit herewith a report of part of the investigations made during 1902 on the duty of water in irrigation and on some of the practical questions connected with its distribution and use. The report does not, however, include all the investigations made during the year on these subjects. In response to a demand for the facts the results of some of the investigations have been published in advance of this report; hence have not been included. The drainage investigations made in Colorado were described in the Yearbook for 1902, and a preliminary report on the drainage investigations in the vicinity of Fresno, Cal., has been published as Circular No. 50 of this Office. Bulletins giving results of a study of Egyptian irrigation and of the storage of water on the Cache la Poudre and Big Thompson rivers in Colorado have also been published.

The results of investigations of the legal and economic questions of irrigation in Utah have appeared in Bulletin No. 124 of this Office and of similar investigations in Nevada in Bulletin No. 54 of the Nevada State Experiment Station. The latter bulletin gives the results of the cooperative work in that State by Prof. Jay D. Stannard, of this Office.

The results of a number of investigations carried on last year are not included in this report, because the work has not been completed and it has not been thought advisable to await the gathering of further data. Among these are the report of Prof. O. V. P. Stout on his seepage measurements and drainage surveys in California and some of the original investigations by Prof. S. Fortier in Montana of the factors which influence the duty of water.

The present report is, therefore, complete in only one feature—it gives the results of all measurements made to determine the duty of water.

Of the individual reports which it contains that of Mr. Morgan discusses quite fully the conditions of the drainage areas of the streams tributary to Jordan River in Salt Lake County and the effects of these conditions on the flow of the streams. He also shows the losses from these streams and suggests means of saving the water now lost, and points out that considerable sums can well be spent in making this saving. A most interesting experiment has been made

on one of these streams. In the spring flood water is run onto the lands along the upper reaches of the stream for the purpose of storing it in the soil, from which it will drain into the stream during the low-water period of late summer. There is no means of finding out exactly the effect of this practice on the flow of the stream, but it is conceded to be beneficial. This means of storing water is very cheap, and if it is proven effective can be widely adopted. Professor Hilgard, of California, has recommended the same practice for increasing the flow of artesian wells in that State.[a]

The report on the Wood rivers in Idaho by Mr. Stannard is chiefly a study of the losses and gains in the flow of the streams discussed. Mr. Stannard's measurements show large losses from these streams and locate the points where the losses occur. The losses are so large and the demand for water so great that he is of the opinion that it would be practicable to provide special means of carrying the streams over the places where the largest losses occur. This has frequently been done on canals and there seems to be no reason why it would not work equally well on streams.

The Sand Creek Valley in Wyoming, which was studied by Mr. Fleming, presents two questions—the best use of water in the production of forage and the effect of the diversion of the water of Sand Creek in Colorado on the supply to Wyoming users. The altitude of this valley and the climatic conditions are such that little beside forage crops, vegetables, and grain can be raised. It is therefore devoted to the live-stock business. Mr. Fleming concludes that in the hay meadows the native grasses have been killed out and replaced by less valuable kinds on account of the use of too much water. He recommends the use of alfalfa and other forage plants not native to this region. For the ranges which have been injured by overstocking he recommends rest in order that the native grasses may reseed the land. Within the last year the water of Sand Creek has been diverted in Colorado to the injury of the Wyoming users, and a case dealing with the interstate phases of this question is now pending in the United States court. Mr. Fleming has made an estimate of the loss to the ranchers on Sand Creek on account of these diversions in Colorado. The water produces much more valuable crops in Colorado, but the Wyoming parties first used the water. While Sand Creek is a small stream, the case is of great interest on account of its bearing on the use of the larger interstate streams.

Professor Waller's report on the duty of water in Washington shows that the quantity of water used by the farmers under the Sunnyside Canal has steadily decreased during the years covered by his studies, but the canal still supplies more than 9 acre-feet for the land irrigated. The use of such excessive quantities of water has raised the ground

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 124.

water to the surface in many places, and so near it in others that large areas have been made unfit for farming. This Office is now making surveys and working out plans for the drainage of this swamped land, but a great deal toward that end could be accomplished by a more careful use of water.

Professor Fortier's report shows that more water was used by the farmers in Montana in 1902 than during the time covered by his previous measurements. This was on account of the large supply furnished by the streams. He reports also a large number of measurements of the duty of water on special crops.

Stony Creek, California, flows through a region which is very largely devoted to the raising of wheat without irrigation. The report on that stream shows that on an average wheat grown without irrigation returns about $7.50 per acre per year, while alfalfa, which requires irrigation, brings an average of $32 per acre per year, showing the great advantage of irrigation to this region. A number of farmers along this stream have built reservoirs for impounding storm water, and have found it very profitable.

The report on irrigation in the Black Hills shows that the impounding of storm water is profitable in that region also. Water wheels turned by the streams are also much used to lift water for irrigation. The large mining camps in this region provide a good market for all that is raised by the farmers, making agricultural land and water very valuable. Those renting water for irrigation pay from $1.50 to $2.50 per miner's inch.

The second report on the rice industry in Louisiana and Texas shows that many of the streams do not supply the demands made upon them by the rice growers. Salt water pumped from the streams has not only killed a great deal of rice, but is injuring the land by depositing salt in the soil. The great need of Louisiana, according to Mr. Bond, is some method of restricting the establishment of irrigation plants on a stream to the number which the stream can supply, or the recognition of the doctrine of priority, so that newcomers may not bring ruin upon the former settlers as well as themselves. The short supply of fresh water in the streams has led to the sinking of a large number of wells. Here also there seems to be a tendency to push matters too far and exhaust the underground supply of water. Pumping, in 1902, lowered the level of the ground water 12 to 15 feet in some localities, and it remains to be seen whether it will come back to its former level. Professor Nagle, in his report on the Brazos and Colorado rivers, also notes a tendency to put more land in rice along those streams than they can supply.

Professor Nagle has continued his measurements of the silt carried by the streams of the Southwest. His general average for the Brazos for the three years and five months covered by the measurements is 1.2 per cent of silt by volume at the end of one week's settlement and

0.9 per cent at the end of one year's settlement. He thinks the Brazos fairly represents the streams of the State of Texas.

The season of 1902 in the East was wet, and irrigation was generally unnecessary. Professor Waters reports that no irrigating was done during the season at the Missouri Experiment Station, but the effects of the water applied during the preceding dry season are reported. Strawberry plants watered in 1901 produced in 1902 from 151 to 874 per cent more berries than plants not watered in 1901. Apple trees watered in 1901 showed no effects of this treatment in the crop of 1902. Nursery stock irrigated in 1901 made a large growth, but many predicted that it would not stand the winter well. The winter of 1901–2 was very severe, but these trees came through without injury and made good growth during 1902. Asparagus irrigated in 1901 yielded 23 per cent more in 1902 than that not watered and the asparagus was of much better quality.

No irrigating was done at Madison, Wis., on account of the wet season. Observations were made to determine the effect on the land of irrigation in previous years. Where land had been manured in previous years no difference in the yields on lands irrigated and those not irrigated were observed in 1902, but on land which had not been manured the plats formerly irrigated did not yield so well as those not irrigated.

Experiments in former years proved that irrigation of vegetables and small fruits in New Jersey is profitable, and Professor Voorhees's report for 1902 is a study of methods of distributing and applying water. He found that open ditches lost large percentages of the water turned into them. Tarred canvas used as a ditch lining proved very effective and not expensive. Clay thrown in the water and puddled did not do so well. Professor Voorhees also gives the records of wells in several sections of New Jersey, in order to show the possibilities of this source of water supply.

Mr. Smith's report on pumping water in the Hawaiian Islands gives valuable data on the efficiency and cost of operation of various kinds of pumps. There are few places in this country where such great outlays for pumps as are reported for the Hawaiian sugar plantations can be profitably made, but the data is valuable nevertheless. The pumps of the Oahu plantation cost $143.63 per acre served, and those on the Ewa plantation cost $172.85 per acre irrigated, while the cost of irrigating sugar cane on this plantation in 1901 was $35.72 per acre.

The publication of this report as a bulletin of the Office of Experiment Stations is respectfully recommended.

Respectfully,

Elwood Mead,
Chief of Irrigation Investigations.

A. C. True, *Director.*

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REPORT OF IRRIGATION INVESTIGATIONS, 1902.

IRRIGATION IN MOUNTAIN WATER DISTRICT, SALT LAKE COUNTY, UTAH.

By E. R. Morgan,
Agent and Expert in Irrigation Investigations.

THE SECTION STUDIED.

Investigations were made during the year 1902 over the area drained and irrigated by the streams tributary to Jordan River. This area includes that part of Great Salt Lake Valley which lies southeast of Great Salt Lake between the Wasatch Range of mountains on the east and the Oquirrh Range on the west. Salt Lake City lies in the northern part of this section and, with the area lying south and east of it, is the one of the most importance, and therefore has received the most attention.

The object of this report is to present some of the problems which those interested in irrigation in this region are trying to solve and to state some of the facts and conditions which have brought them about.

GREAT SALT LAKE VALLEY.

Great Salt Lake Valley lies in the north-central part of Utah. The Wasatch Mountains on the east rise almost perpendicularly to a height varying from 8,000 feet to nearly 12,000 feet above sea level, or from 3,500 feet to 7,500 feet above the valley. The entire valley was, during geological times, filled by an ancient lake, now referred to as Lake Bonneville. The old shore lines formed by the water at different levels of the lake can still be seen plainly on the mountains on either side of the valley. Along the margin of this ancient lake, which is also the eastern boundary of Great Salt Lake Valley, alluvial fans and deltas exist at the mouths of canyons opening into the valley. These alluvial fans or cones, formed at short intervals by the streams issuing from the canyon openings, merge and present the appearance of almost continuous terraces. In some cases the existing stream has cut through the delta which it built in the ancient lake, revealing a section from which the nature of the formation and soil can be determined. On the west side of the valley the same agencies have been

working with results much the same but on a much smaller scale, primarily on account of the western drainage area being smaller as well as less conducive to precipitation.

That part of the valley lying south of Salt Lake City, about 22 miles in length and varying in width from 4 miles at the extreme south to 17 miles at the north, includes the area under consideration. The east side of the valley slopes toward the west and on the west the slope is eastward to the Jordan, and there is also a gradual rise from the north toward the south end of the valley. As a result the streams from the east side of the valley, with the exception of City Creek, which flows in a southerly direction, flow west and northwest, while those on the west side of the valley flow in a northeasterly direction. Jordan River, the outlet of Utah Lake, which is situated in the next valley south, flows through the valley a little east of the middle in a direction almost directly north. After having its waters diverted for irrigation it collects the seepage or return water from both sides of the valley, and some of this water is again used for irrigation and power on the west side. The water which enters the river below these places of diversion is conveyed to Great Salt Lake, entering at a point northwest of Salt Lake City.

IRRIGABLE LANDS.

In Salt Lake Valley east of Jordan River, the section to which attention is particularly invited, the irrigable lands aggregate about 105 square miles, of which about 12.5 square miles are included within the limits of Salt Lake City. There are also small tracts of irrigable lands lying along the stream beds of Parleys and Emigration Canyon creeks.

SOIL.

The soil is generally fertile and, when a sufficient quantity of water is properly applied, very productive. The different kinds of rocks of which the Wasatch Mountains are composed are, for the most part, the sandstones, limestone, quartzite, and granite. The soils resulting from the disintegration of these rocks are sandy, limy, and clayey in nature. The deltas and alluvial cones near the mouths of the canyons consist of a heterogeneous mass of partially disintegrated stone and gravel mixed with finer gravel, sand, and marl. These are called bench lands and extend along the foothills and into the valley for varying distances depending among other things upon the size of the stream. From the surface to a depth of from 1 to 3 feet disintegration is in an advanced stage, while the underlying material is coarse and porous. As the central part of the valley is approached the soil becomes finer although it still contains gravel and coarse sand. The reason given for this is that the lesser slope of the streams and the

increased width decreases their carrying capacity and only the finer material is carried to these and the lower portions. In the lower parts only very fine gravel, sand, and marl are found.

This is, in general, true of all of the streams and their deposits and the result is that there are three reasonably well-defined tracts of land which gradually blend from one into another and extend through the valley. The lowest tract requires little or no irrigation and produces hay and pasturage principally, although some grain and hardy fruits are raised. On nearly all of the streams the middle portions were first irrigated and cultivated for the reasons that it was and is yet the best land for diversified agriculture and, too, fewer and less serious obstacles had to be overcome in diverting the water onto the land. This middle tract is more thoroughly cultivated than either of the other two and produces in abundance nearly any crop adapted to the climate. The greater part of the bench lands is yet to be reclaimed, as the water supply, as used at present, is insufficient to meet the demands of even the lower sections during the latter part of the season. On account of being protected from winds and frosts and the nature and fertility of its soils, the bench land is particularly adapted to the production of fruits, which would find a ready and profitable market in Salt Lake City. This land, however, requires a large supply of water on account of its porous nature.

WATER SUPPLY.

Here, as in other sections of the intermountain region, the source of water supply is in the mountains. If this supply were properly stored, judiciously divided, and economically used it would be not only reliable but probably sufficient to meet all demands.

The Wasatch Range on the east of the valley, with its high and precipitous summits partially covered with timber and heavy undergrowth, cut here and there by deep, narrow canyons from which lead smaller well-protected gorges and ravines, serves not only to condense the moisture which would otherwise pass over the region, but also as a natural reservoir from which the streams derive a constant supply (Pl. I). On the other hand, the Oquirrh Range of mountains, on the west of the valley, is comparatively low, rolling, and covered with a scanty growth of pine, quaking asp, scrub oak, and underbrush. As a result, the streams entering Jordan River from the west are small and unimportant compared with those on the east side of the valley.

The streams tributary to Jordan River, commencing with City Creek and proceeding south on the east side of the valley, named in the order of their occurrence are: City, Red Butte Canyon, Emigration Canyon, Parleys Canyon, Mill, Neffs Canyon, Big Cottonwood, Little Cottonwood, North Dry, Middle Dry, South Dry, Rocky

Mouth, and Big Willow creeks, all of which find their source on the western slope of the Wasatch Range and flow, generally speaking, in a westerly direction toward Jordan River. Those on the west side are Butterfield Creek and Bingham Canyon Creek, which find their source on the eastern slope of the Oquirrh Range and flow in a northeasterly direction toward Jordan River.

CITY CREEK.

City Creek is of interest from a historic point of view from the fact that from this stream the Mormon pioneers first diverted water for irrigation, and it is still interesting because it is one of the chief sources of Salt Lake City's water supply. It rises in the summits of the Wasatch Mountains, in Salt Lake County, about 9 miles northeast of Salt Lake City, and flows in a southwesterly direction through a canyon of varying topography. It has a drainage area of 19.15 square miles. Near the head of the canyon its sides are steep, high, and partially covered with a growth of pine, quaking asp, birch, and maple. Smaller canyons lead from either side and in turn are divided into numerous gorges and ravines. Those leading toward the south are well protected from the sun and wind and afford protection to the winter's snow and so serve as natural reservoirs. From the head of the stream toward its mouth the walls of the canyon become less steep, the growth of timber more scanty, the occurrence of well-protected side canyons and gorges less frequent until, near the mouth of the canyon, low rolling hills covered with oak and sagebrush are the predominating features.

At the mouth of the canyon is the delta which was deposited in Lake Bonneville during the period of its higher levels and upon which is built a large part of Salt Lake City. After the recession of the lake the water of this stream cut through the delta and revealed a structure indicative of its origin.

When the pioneers entered the valley City Creek was divided into two branches, one of which flowed in a westerly direction, practically where the City Creek aqueduct on North Temple street was afterwards constructed, the other south on what is now Main street. Water from both branches was used somewhat for irrigation before any surveys were made. When the city was surveyed into blocks, lots, and streets, previous to the Government survey, the ditches first constructed were abandoned and destroyed. New ones were so constructed as to convey the water from the west branch past the blocks and lots in what are now called plats A, B, and C. Part of the water in the south branch was used for irrigation along its banks, the remainder flowing south united with Red Butte, Emigration, and Parleys Canyon streams, which were then used on the 5 and 10 acre farming lots adjacent to the city. The water was divided into what

was considered to be good irrigation streams, which were used in turns or at regularly recurring intervals. The system of rotation in use was in principle the same then as now, except that at the beginning there was plenty of water available for all in the daytime, and it was used at night only from choice. Later all of the water of City Creek was used in the city. The construction and maintenance of ditches and flumes and the distribution of water were placed under the direction of a water master in order to more effectively control the water supply. The ditches were constructed by the owners of the land, the labor being apportioned according to the number of acres the individuals expected to irrigate. No cash assessments were made; in fact, there was no money with which to pay such assessments. No one had anything to sell to another had there been a circulating medium; all was done by the common consent and through the united efforts of the people.

Several years passed after the settlement of Utah began before the Government surveyed the lands. During this time property was held by squatter's rights and those titles were invariably respected until the Government surveys were made and the proper titles perfected and transferred. After provision had been made for the proper transfers, the land carried with it the right to the use of the water which had previously been used upon it, which gives the impression that the water was appurtenant to the land. However, the right to the use of water was sometimes changed from one place to another by the mutual consent of those interested. These conditions existed with little modification until a waterworks system was installed in the city, when the flow of the stream was turned into the mains and its management placed in the hands of the city officials.

At present the city engineer has charge of the active and proposed construction work, the superintendent of waterworks is responsible for the distribution of the water, while the land and water commissioner is charged with the duty of seeing that the city ordinance prohibiting the making of camp fires and the grazing of live stock, especially sheep, within the bounds of its drainage area are strictly enforced. For the present discussion the duties of the land and water commissioner are the most important. In the late summer and early fall the weeds, grass, and some of the undergrowth are very dry and would aid in the rapid spread of mountain fires if allowed to start, greatly imperiling the water supply for years afterwards. When the steep hillsides have been robbed of their vegetation the soil and vegetable mold are easily washed away by the storms and melting snow of the following seasons. The conditions so produced are favorable to an early run off, which is to be avoided, and also to snow slides in times of abundant snow fall. At first thought it would seem that these great heaps of snow, remaining sometimes longer than does any of that

which lies where it was first deposited, would be conducive to a later supply of water. But inside of a few hours after this snow is melted it finds its way to the stream and runs off. Besides this, snow slides destroy a great amount of timber and remove the soil from the hills over which they descend, producing the very conditions which are to be avoided. On the other hand, if these avalanches could be prevented and the soil and timber were to remain in place, even if the snow melted sooner the water would slowly percolate through the soil, be retained for a time, and find its way to the stream gradually, thus decreasing the flood water and increasing the later supply. The excessive grazing of stock on this area would not only pollute the water, but destroy the underbrush and harden the soil, and thus render it less pervious to and retentive of water and in that way increase the early run off which, in turn, tends to remove the much-needed soil from the hillsides.

The efforts of the city officials to keep fires from ravaging the vegetation on the mountains, thereby preserving their effectiveness as natural reservoirs, are to be commended and their example should be more generally followed throughout the intermountain region. While the custom of preventing stock grazing on the streams which supply cities and towns with water is equally commendable, the live stock industry in Utah is too important to be needlessly interfered with. Just how much one industry should gain at the loss of another is a question of some moment and should receive consideration before definite action is taken.

The accompanying table shows the average daily discharge of City Creek in cubic feet per second from November 1, 1901, to October 31, 1902, with the exception of a few days in the latter part of May and the first part of June, during which time the discharge was so great that it could not be measured with the device used. It probably reached 100 cubic feet per second at times.

Average monthly discharge of City Creek from November, 1901, to October, 1902.

Month.	Cubic feet per second.	Month.	Cubic feet per second.
1901.		1902—Continued.	
November	6.94	April	13.39
December	6.36	May	34.83
		June	25.28
1902.		July	13.56
January	5.84	August	9.22
February	5.48	September	7.13
March	5.75	October	6.74

The following table shows the maximum, minimum, and average discharge in gallons per day, this being the unit of water supply for most cities and towns.

Maximum, minimum, and average discharge of City Creek, in gallons per twenty-four hours, for each month from November 1, 1901, to October 31, 1902.

Month.	Maximum.	Minimum.	Average.	Month.	Maximum.	Minimum.	Average.
1901.				1902—Cont'd.			
November ...	4,808,160	4,221,872	4,497,120	April	15,098,400	3,856,032	8,676,152
December....	4,419,360	3,856,032	4,119,280	May	36,971,152	12,882,240	22,567,680
				June	24,487,448	10,774,070	16,381,440
1902.				July	11,171,520	6,914,592	8,579,520
January	4,415,040	2,767,392	3,887,872	August	6,694,272	4,864,320	5,974,560
February	3,856,032	2,332,800	3,532,032	September ..	5,009,472	4,419,360	4,613,760
March	3,980,680	3,884,072	3,713,472	October	4,419,360	4,322,590	4,367,520

The measurements were made over a Cippoletti weir, gagings being made in the morning and evening of each day and an average determined from the two gagings. Most of the precipitation in this section occurs from November to the following May and, in order to determine the run off of the precipitation period, measurements were taken during the time covered by the table. Reference to the table will show that the greatest average daily discharge occurs during the months of April, May, and June, when showers are more frequent and less water for the sprinkling of streets and irrigation of lawns and gardens is needed. During these months there are, therefore, great quantities of water available for storage. With this end in view the city has selected several reservoir sites, which it expects to improve. The expense that will probably be incurred in so doing, however, will be above the average per acre-foot of water stored, because the natural conditions are not the most favorable.

The natural conditions on this stream favor the generation of power on a small scale. Several filings with this object in view have been made.

RED BUTTE CANYON CREEK.

Red Butte Canyon Creek rises in the mountains about 1 mile south of the head of City Creek and flows through its canyon for about 5 miles before it emerges upon the United States military reservation where Fort Douglas is situated. Its drainage area is estimated to be about 8 square miles. The canyon walls are quite steep, but not so high as those of City Creek Canyon. The side canyons are few and small and but poorly protected from the sun. The hillsides and ridges are clad with sagebrush, scrub oak, mountain mahogany, and near the head of the canyon can be found pine, while birch and maple grow to some extent near the creek bed. The discharge of the stream was not measured during the period covered by the season's investigations, but from measurements made during 1900 and 1901 it was learned that the discharge varies from 10 cubic feet per second in late April or early May to 1 cubic foot per second during the hardest freezing weather of the year. The average discharge for July, August, and September is probably about 2 cubic feet per second.

As was stated in the discussion of City Creek, the water of Red Butte was first used on the farming land just south of the city. From the meager information which could be obtained its use here and in the eastern part of the city was continued until Fort Douglas, located by Gen. P. E. Connor in September, 1862, was built and occupied. Since that time the United States War Department has had control of the water of this creek. During April, May, and part of June there is usually an excess over the needs of Fort Douglas, which is used in the eastern and western parts of the city. In addition to supplying the fort with water for culinary use, sprinkling of streets, and the maintenance of several ornamental ponds this stream irrigates approximately 50 acres of orchards, gardens, and alfalfa fields during the summer and supplies water for several ice ponds during the winter, all being maintained for the comfort and convenience of those occupying the fort. The waterworks system is simple and effective, consisting of a cement-lined reservoir to store the night flow which would otherwise be wasted, a pipe line leading from it to the fort, and the distributing pipes.

EMIGRATION CANYON CREEK.

Emigration Canyon is the gateway through which the Mormon pioneers entered and from whose mouth they first beheld Salt Lake Valley, July 24, 1847, the day which will forever be memorable to the people of Utah. The canyon opens into the valley about 5 miles southeast from the business part of Salt Lake City. About 8 miles northeast of this point the stream rises. It has a drainage area of 18.92 square miles. The sides of the canyon are low and at places separate so far as to leave small tracts of irrigable lands along the stream. On the south side of the canyon a series of ridges with intervening ravines gradually rises to the top of the drainage divide. The lower half of the north side is essentially the same, but from the upper half a number of side canyons lead, from which comes the greater part of the flow of the stream.

The area drained is covered for the most part with sagebrush and scrub oak, there being a few pines near the head of the stream, some cedar and mountain mahogany on the ridges, and some birch and maple near the stream bed. The natural features of the area do not favor either a great precipitation or a late retention of what falls. As a result the stream is comparatively unimportant. In addition to the United States military reservation, which lies below and to the north of the mouth of the canyon, there are about 2,000 acres of land susceptible of irrigation from Emigration Canyon Creek. The sandy and gravelly nature of the soil, together with the protection from frosts and winds afforded by the adjacent mountains, admirably adapts this tract to the production of fruits. However, on account of the

scanty supply of water furnished by the streams, only about 400 acres are made productive, the greater part of which produces only grain or alfalfa. Some fruit and garden vegetables of an excellent quality are also grown.

The accompanying table shows the average discharge of Emigration Canyon Creek in cubic feet per second for each month from November, 1901, to October, 1902:

Average monthly discharge from Emigration Canyon Creek from November, 1901, to October, 1902.

Month.	Cubic feet per second.	Month.	Cubic feet per second.
1901.		1902—Continued.	
November	1.20	April	9.62
December	.93	May	9.92
		June	4.90
1902.		July	2.02
January	.60	August	.78
February	.87	September	.52
March	1.46	October	.69

The flow during November was probably affected by early storms and during late December and January by cold weather, while there were great fluctuations in April, probably due to sudden changes in temperature. The total discharge for the year, calculated from the average daily flow for each month, is about 2,023 acre-feet, nearly three-fourths of which runs away during April, May, and June. The early run off is accounted for partly by the topography of the area, its poorly protected side canyons and the scanty growth of timber, and partly by the fact that this canyon is used as the highway, or what is known locally as the stock trail, which all stockmen are compelled to take when driving the stock from the winter to the summer ranges and back. Thousands of sheep and cattle are driven through it twice a year and ranged or fed on its sides before or after passing through the valley where no stops can be made. As a result the soil is packed and the growth of timber is almost entirely prevented.

A comparison of the drainage area and total run off of this stream with those of City Creek is very interesting. The drainage area of Emigration Canyon Creek is only 0.23 square mile less than that of City Creek. The slope of its canyon walls is less, but its bottom and sides for a considerable distance up are packed hard by the herds of stock that pass over it, the latter condition tending to favor a rapid run off. Although the conditions in City Creek drainage area on the whole naturally favor a quicker run off, they hardly account for the fact that the latter creek discharged 8,597.11 acre-feet, or over four times the amount discharged by Emigration Canyon Creek during the same time. During the month of May alone City Creek discharged 100 acre-feet more than the total discharge of Emigration Canyon

Creek for the year. This can be accounted for partly by a difference in precipitation over the two areas, the care which City Creek receives, and the use to which Emigration Canyon Creek is put. If these reasons are accepted, a valuable lesson can be learned from a comparison of the conditions of the two streams and the causes producing them, and further investigations can be made with profit. But the tracts drained by each are adjacent, and the differences in precipitation, topographic features, growth of timber, and conditions of the soil do not seem to be sufficient to account for the great difference in the run off. In explanation of this it has been suggested that a large percentage of the precipitation over the Emigration Canyon Creek area finds its way to Great Salt Lake or elsewhere through underground channels. This seems probable on account of the inclination of the strata adjacent to the canyon. So plausible is this theory that the Sells Lime, Cement, and Rock Company, promoted by business men of Salt Lake City, located and filed on the subterranean waters of what was considered to be water-bearing strata near the mouth of the canyon. A vertical shaft was sunk on the land with the intention of intercepting the water-bearing strata and providing for the water a drainage sump from which it could be either drained by tunnels or pumped to the surface. The expense was so great that the scheme had to be abandoned, although it was claimed by the company that the indications were good.

Salt Lake City also undertook to develop water here, and the municipal authorities were partially successful. A small level space about one-fourth of a mile up the canyon was selected as the place upon which the undertaking should be tried. An excavation 35 feet deep, about 15 feet wide, and 175 feet long was made across the bed of the stream. The object of this excavation was to intercept the underground current at and above bed rock and offer a path of less resistance for its flow. It was also intended to make the lower face of the sump water-tight and drain off the inflow near the top of the pool, but before bed rock was reached the flow of water into the sump was such that the work could not be finished as was originally intended, there being no outlet to the sump. Pumps were employed, but their capacity was exceeded by the inflow, so, on account of expense, work was suspended. However, considerable water was developed, and a pipe line entering the side of the sump and leading to the city mains drains off the water as it collects there. The natural flow of the stream for a considerable distance above and below the sump was flumed so as to prevent it from entering the sump. Some springs came from the side of the canyon previous to digging the sump, and these were cleaned and deepened and their discharge was run into the sump. The flow through the pipe line is nearly constant at 2.3 cubic feet per second during most of the year, although it sometimes reaches 2.9 cubic feet per second.

Since the city ceased work on the sump, private parties have sunk a shaft near it and encountered bed rock at a depth of about 50 feet. In this shaft about 24 feet of water stands constantly, which is supposed to be a good indication of the possibilities there. It is possible, if a tunnel were to be driven from a point far enough down the canyon to give it the required fall and to strike bed rock under the sump, and then, if the latter were to be lowered to bed rock and extended to the side walls of the canyon, that a considerable quantity of water could be developed. The tunnel would act not only as an aid in deepening the sump but also as a permanent drain to it. Notwithstanding the facts that water in this section is very valuable, and that the indications are good, the expense already incurred has been so enormous for the amount of water developed that it is questionable whether anything more will be done until the geological features of the canyon are more thoroughly known.

The water of Emigration Canyon Creek, as has been previously stated, originally united with the waters of City, Red Butte, and Parleys Canyon creeks and was used for irrigation on the farms south of the city. Just how long it was used there can not be stated positively on account of the imperfectly kept records, but it is probable that the time was short. The people of the First, Second, and Tenth bishop wards[a] of Salt Lake City were the first to acquire recognized rights on the streams. They diverted the entire flow of the stream, except during the flood season, at a point between the present site of Wagner's brewery and the city's sump referred to. Below this point a considerable amount of spring and return seepage water from the creek bed above found its way into the creek bed and was diverted and used on what was then called the east bench, or on secs. 10 and 15, T. 1 S., R. 1 E., Salt Lake base and meridian. These conditions existed until 1876, when those interested in the first diversion, for their own convenience and to accommodate the owners of property through which their ditch ran, moved the place of diversion to its present site, which is about one-fourth of a mile below Wagner's brewery. Water, even at that time, was valuable and a conflict in claims to the water of the stream soon arose. Not even approximate measurement of the flow had been made, the judgment and memory of those interested being the only aids in the solution of their difficulties. The inhabitants of the east bench claimed that prior to the change in the location of their head gates the ditch carried as much water as did that belonging to the city, and at times they were allowed to take what was thought to be one-half of the flow at the new place of diversion. More or less difficulty

[a] For the administration of its affairs the dominant church of Utah has divided Salt Lake County into three primary divisions which are known as stakes, each presided over by a president. These are again divided into a number of wards, over which bishops preside. It is to these latter divisions that reference has been made.

was experienced in the division of the water at this point until 1880, when, upon application of those interested, the water commissioners[a] arbitrated or adjudicated the rights to the water of the stream.

After considering the facts presented by both sides, the water commissioners decided as follows: That the people residing on the east bench should have a primary right to one-seventh of the natural supply of the stream, including the water of the springs, during the whole year for culinary purposes, and a primary right to the surplus water of the creek for irrigation and culinary purposes, and that the citizens of the First, Second, and Tenth wards of Salt Lake City should have the remaining part of the natural flow for irrigation and culinary purposes, providing that the place of diversion should not be changed to any point east of where the water was then diverted.

No further difficulty was met with in the divisions until the city dug the sump and turned the spring water into it, when the citizens on the east bench refused to take one-seventh of what was left as their share. They claim that, in addition to taking the pure spring water in which they were interested, the sump had decreased the natural flow of the stream, notwithstanding the precautions taken. As a temporary provision, the city has given them for some years past one-third of the natural flow of the stream. According to the decision of the water commissioners in 1880, the citizens of the east bench are entitled to the first right to the surplus water of the stream, and, as the city has at this time of the year a good supply from other sources, the most of the early flow goes to the farmers.

A few small ranches in the canyon are irrigated with the early flow of the streams and from springs which have been developed. It is supposed that part of the water used in the early part of the year finds its way to the stream and increases the natural supply later in the season.

The following table shows two-thirds of the maximum, minimum, and average discharge, in gallons per twenty-four hours, of Emigration Canyon Creek, to which has been added the discharge of the pipe line leading from the sump, taken to be 1,500,000 gallons per twenty-four hours. These are factors in Salt Lake City's water supply.

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[a] The county selectmen of the several counties of the Territory of Utah were created ex officio water commissioners by the act approved February 20, 1880. Their duties were to make observations of the quantity of water in the natural sources of supply, and determine the average flow at all seasons of the year, to hear and determine all claims to the use of water, and on receiving satisfactory proof of any right to the use of water of any stream to issue to the person owning such right a certificate which, according to the law, was to be recorded by the county recorder of the county in which the stream was located.

Two-thirds of the maximum, minimum, and average discharge of Emigration Canyon Creek, in gallons per twenty-four hours, together with the discharge from the pipe line, from November 1, 1901, to October 31, 1902.

Month.	Maximum.	Minimum.	Average.	Month.	Maximum.	Minimum.	Average.
1901.				1902—Cont'd.			
November ...	2,126,588	1,919,040	2,018,400	April	9,850,560	2,450,400	5,655,264
December....	2,256,388	1,716,000	1,901,184	May	8,800,170	4,567,200	5,790,048
				June	4,968,672	2,708,448	4,536,800
1902.				July	2,847,840	1,906,080	2,372,640
January	1,759,200	1,759,200	1,759,200	August	2,092,128	1,746,240	1,836,960
February	2,057,338	1,759,200	1,874,840	September...	1,759,200	1,716,000	1,724,640
March	2,515,200	1,802,400	1,992,480	October......	1,845,600	1,763,520	1,789,440

PARLEYS CANYON CREEK.

Parleys Canyon Creek, the next stream south of Emigration Creek, is fed for the most part by numerous streams which rise on the main ridge of the Wasatch Range, between a point just east of the head of Emigration Canyon Creek and a point along the same divide, 10 miles distant in a southwesterly direction. Almost midway between these points a low ridge extends from the top of the divide to the bottom of the canyon. On either side of this natural division the small streams unite to form the north and south forks of the creek. Above their confluence the north fork flows southwesterly and the south fork northwesterly. Below the forks are a number of small streams which find their sources in the high peaks on the south side of the canyon. The creek below the forks flows in a direction a little south of west and drains an area of 50.14 square miles.

The canyon opens into the valley about 2½ miles from and a short distance east of the mouth of Emigration Canyon Creek. For a few miles above its mouth the canyon is narrow, its sides steep. In the bottom of the canyon maple and birch grow, the sides are covered with scrub oak, and toward the top some pines are found. From the south side of the canyon lead a number of side canyons which are pretty well protected from the sun. A little below the forks the canyon widens, that part from which the north fork comes appearing from an elevated point like a valley filled with low, rolling hills. The area drained by the south fork is also comparatively rolling, but the ground is higher and better protected by vegetation. The characteristic features of the whole area from a short distance below the forks of the stream up to the divide is the valley-like canyon with its low, receding sides covered with scrub oak and undergrowth of various kinds. Toward the head of both forks, in the well-protected gorges and ravines and on the intervening ridges, grow pines and quaking asps. Along the bottom of the canyon are quite a number of irrigated ranches and considerable areas of irrigable land. On the whole the area is poorly protected and not adapted to act as a natural reservoir on account of its low hills and the scarcity of timber.

The accompanying table shows the monthly average discharge of Parleys Canyon Creek, in cubic feet per second, from November, 1901, to October, 1902, with the exception of the month of May, a few days in the latter part of April, and the early part of June. The measurements were made over one 2½-foot and two 5-foot Cippoletti weirs which were fastened to the same framework with their crests on the same level. Readings were taken nights and mornings and the average of the two discharges taken to be the discharge for the day:

Average monthly discharge of Parleys Canyon Creek from November, 1901, to October, 1902.

Month.	Cubic feet per second.	Month.	Cubic feet per second.
1901.		1902—Continued.	
November	8.19	April	27.75
December	7.69	May	....
		June	24.13
1902.		July	13.39
January	7.04	August	10.64
February	7.38	September	7.56
March	7.35	October	7.49

During the time of the missing measurements the stream was so high that it could not be measured with the devices used. It is probable that during May the average flow of the stream at the place of gaging was about 80 cubic feet per second. But during April, May, and June large quantities were diverted onto the ranches, side hills, and flats in the canyon, which decreased the flow from the area at this time. So the lesson to be learned from the measurements is that the natural tendency, as would be expected from the topography, is to discharge the greater part of the run off during April, May, and early June.

The object of diverting water, as referred to above, is to run large volumes of it on the land during the flood season when otherwise it would be wasted, in this way increasing the natural supply later in the season, or storing it by what is known locally as the swamping method. To accomplish this a series of ditches was dug on the ranches which were purchased by Salt Lake City primarily for the water rights which the owners had acquired. These ditches are kept full and the intervening spaces covered with water where the slope will permit. It is aimed to supply the water at a rate not greater than it is absorbed by the soil so as not to produce washes. The effect of this method of storage on the flow of the streams and the rights to its waters will be discussed later. Besides the irrigable land in the canyon, there is a tract extending about 2 miles north and south and from the canyon to Jordan River, which is susceptible of irrigation from Parleys Canyon Creek. Of this there is a strip 1½ miles wide along the Jordan that needs little or no irrigation, some of the remainder is irrigated from Emigration Canyon and Mill creeks, while most of the bench land near the mouth of the canyon is not irrigated at all.

The bottom, middle, and bench lands are well defined in this tract. The bottom lands are used for pasturage and to produce hay; the middle lands are intensively cultivated and irrigated and yield various crops. The bench lands are well adapted to the production of fruit where water can be obtained. There are 2,479 acres which have a primary right to the water of the stream and 452 acres still use it, while the use of 2,027 acres of right,[a] or a little over 80 per cent of the stream, is given to Salt Lake City in exchange for a quantity from the Jordan and Salt Lake City Canal. The rights to the waters of the stream are becoming somewhat complicated and a study of their development is interesting.

Although no water from Parleys Canyon Creek was used for irrigation during the year of the pioneers' arrival, construction work on some of the ditches was done and irrigation on this stream began with the opening of the next season. The records of the stream previous to 1879 are very meager. Most of the little information obtained was solicited from the older inhabitants, and just that part which has to do with the developments of the present rights is presented. There was plenty of water for all appropriators until 1877, and especially so after 1853, when Brigham Young took part of Mill Creek, the next stream south, over the bench between the two streams, and ran it into Parleys Canyon Creek. The combined flow was used to generate power to run woolen mills and a tannery, below which it was used for irrigation.

About 1876 the claim to Mill Creek water was relinquished and this water then reverted to its former owners. This transfer materially decreased the supply below the mills, but it was made by mutual consent of those interested, no legal proceedings being necessary. In 1877 application was made to the county court for the privilege of using the surplus water of Parleys Canyon Creek for irrigation, which shows that all the natural flow of the stream had been appropriated. Other rights to the surplus waters were granted, but the records of these as well as of the primary rights were poorly kept. This unsettled condition continued until 1880. Then came the laws referred to in the discussion of Emigration Canyon Creek, and in the latter part of that year the water commissioners adjudicated the primary[b] and

[a] The origin and use of the term "acre of water right" resulted from the way the adjudications and arbitrations were made. It means the amount of water at the different stages of the stream to which 1 acre of land is entitled. If there are 1,000 acres of land owning primary water rights in a stream it is held that each acre is entitled to one one-thousandth of the discharge below the normal flow, regardless of the date of appropriation or the character of the soil. An acre of water right is, therefore, not any particular volume of water, but a certain proportion of the stream.

[b] Primary rights are the rights to the use of water at or below the natural flow of the stream, all being equal regardless of priority of appropriation. Secondary rights are operative only during the flood season or at such times as the primary rights are fully satisfied. The earliest appropriators of the surplus take water first and are the last to be shut off when the stream is approaching its normal flow.

secondary rights to the water of the stream. The result of the adjudication is given below. For convenience, the flow of the stream at the highest point of diversion was said to contain 60 shares, each of which, or one-sixtieth of the flow at its various stages, was supposed to irrigate or to be the amount of water to which each 44.5 acres was entitled. The following table shows the names of the ditches interested in the adjudication, the number of acres of primary and secondary water rights and the number of shares in the stream awarded to each, also the rights as they exist at present:

Results of the adjudication of Parleys Canyon Creek in 1880.

Ditch.	Number of acres primary right.	Number of acres secondary right.	Number of shares in the stream.	Acres of primary right at present.
Turnbow	527.00		11.85	547
Sperry	263.00		6.08	263
Sanders	672.00	15.0	15.01	672
Kennedy	859.25	31.5	19.27	864
Forest Farm	71.00		1.60	76
Factory	5.00		.11	19
Decker	33.00	19.0	.61	33
Winegar	32.00		.61	
Alexander	45.00	15.0	1.00	
Hardy	20.00	30.0	.50	
Armstrong	109.00	120.0	2.66	
Naylor	10.00	30.0	.25	
Olson	10.00		.25	
Paper Mill	4.75		.10	5
M. M. Young	14.00		.33	
Total	2,675.00	260.5	60.23	2,479

In addition to the number of acres of secondary rights shown by the table the Pleasant View Ditch was granted 70 acres, the Taylor Ditch 5 acres, the Hatch Ditch 20 acres, and the John Parker Ditch 10 acres. These grants, together with those given in the table, show that 365.5 acres of secondary right was granted by the water commissioners. Of the 2,675 acres of primary rights granted, the water for 226 acres of right was at that time used on land in the canyon and that for 2,449 acres on the land below its mouth. At present there are 2,479 acres of right below the mouth of the canyon, or 30 acres more than was granted. This right was probably transferred from the canyon, although no record of it was found. Nearly all of the remaining right in the canyon has been sold recently to Salt Lake City.

Although the law of 1880 is generally said to be a poor one, and its validity has been questioned, its workings on this stream and the adjudication made under it seem to have been all that could be expected. It seems that if injustice had been done at the time of the adjudication it would have been discovered and remedied, but reference to the table will show that the rights to-day are very much the same as they were at the time of the adjudication. In the light of to-day's knowledge the adjudicator's knowledge could be criticised only for the basis employed in the division of the stream, which was its discharge at

the highest point of division. If the sum of all the diversions made from it had been used as the amount to be divided among the claimants, then each ditch would have shared the loss or gain by seepage and the problem of distribution would have been made more simple. In addition the stage of the streams at which the secondary rights were to be recognized should have been established.

The work of the water commissioners was accepted by the people, and the stream was divided in accordance with the adjudication until 1888. At that time all the owners of the Sanders, Turnbow, and Sperry ditches and the owners of 545 acres of right of the Kennedy Ditch, entered into an agreement with Salt Lake City. It was agreed that the owners of the rights referred to above, or parties of the first part, should exchange the waters of Parleys Canyon Creek, to which they were entitled, for an equivalent quantity of water from the Jordan and Salt Lake City Canal, and should allow Salt Lake City, or the party of the second part, to take the water from the creek at any point it should choose. It was further agreed that during each season, when the creek had reached its normal flow or when all the water was being used for irrigating by the primary owners, that Salt Lake City should have the flow determined and the board provided for should furnish to the parties of the first part a continuous supply of water from said canal equal to their portion of the normal flow of the creek during the remainder of the season. Salt Lake City also agreed to maintain all existing rights of the parties of the first part to the waters of said creek and to keep in repair its own canal and by its agent, jointly with the agent of the parties of the first part and at the expense of the farmers, to turn from said canal the amount of water due the parties of the first part in the exchange, and also to construct works for the diversion of waters from the canal and creek and to provide the rights of way for the same. It was agreed that if at any time either party should feel aggrieved at the action of the other party as to the fulfillment of this agreement, the board should decide the question at issue and that its decision should be final. If at any time Salt Lake City should fail to furnish the proper quantity of water from its canal, it was agreed that it should not be necessary for the parties of the first part to apply to any court to regain their rights in the water of the creek, but their agent might at once give notice to the city's agent of its failure to furnish said water, and if such default should continue for a period of twelve hours, then the agent for the parties of the first part might at once proceed to turn the creek into its original channel, and all expense incurred in so doing and any damage caused by the failure to furnish canal water should be borne by the city. In case it should happen that the parties of the first part should have to retake the water of the creek, they agreed that the city might again have it on the same terms as were specified by furnishing to the parties of the

first part the water from said canal and sufficient more from that source within a time to be determined by the board to make up for any delays in irrigating caused by the failure; provided that said failure should not continue for a period of six months, in which case this agreement should be null and void and at the option of the parties of the first part whether it should be renewed. It was also agreed that by March 1 of each year the two parties interested should each choose an agent, and these two should select a third to constitute a board, a majority of which could act lawfully and decide all questions arising in reference to this agreement, the expenses and fees of the board to be paid by the city. This agreement was to be perpetual if the covenants and conditions were complied with.

In accordance with this contract Salt Lake City constructed a settling reservoir at the mouth of the canyon and a conduit leading from it to the mains of the city waterworks. The parties entering into the agreement with the city owned 81.7 per cent of the water of the creek, but the owners of the Decker and the Forest Farm or Crismon-Rockwood ditches, the interests in the Kennedy Ditch, lying above the Jordan and Salt Lake City Canal, and the factory and paper-mill interest claimed that they would suffer a greater loss by seepage and evaporation if the exchange were to be made. So the parties to the exchange agreed to take 80 per cent of the flow at the mouth of the canyon and allow the 1.7 per cent for the losses sustained. The remaining 20 per cent is diverted between the mouth of the canyon and a point which is something over a mile above where the Jordan and Salt Lake City Canal crosses the bed of the creek. Between the point of the last diversion and the Jordan and Salt Lake City Canal there is a gain of from 5 cubic feet per second in the early part of the season to 2 cubic feet per second during the latter part of it, due to springs and return seepage. Under the contract the city has the right to take this water and give an equal volume of canal water for it. But the city can not use it to advantage, and it is therefore allowed to flow down and mingle with the canal water after the latter has been measured from the city's canal. In this way the parties of the first part to the above contract have since, as before the contract was entered into, used and claimed this water. After the exchange was agreed upon Salt Lake City bought most of the land with its right to the use of water under the Winegar, Alexander, Hardy, Armstrong, Naylor, Olson, and M. M. Young ditches, all of which are situated in the canyon. During the flood season and until the city's supply becomes short the water is swamped, as has been explained. After this time, usually in August, it is turned down and the weirs so adjusted that 20 per cent of the amount discharged before the transfer was made is allowed to flow down the natural channel and the remainder runs into the city's con-

duit. The city claims that the flow of the stream in the latter part of the season is considerably increased on account of so much being swamped during the flood season, while some of the owners of the stream claim that the swamping has the same effect that irrigation had previously. They also claim that the city ought not to transfer the water from the land in the canyon to its conduit after having already used more of it than did the previous owners.

These conditions have been developing from 1888, but no serious trouble was experienced until the season of 1902. During early August the flow of Jordan River from Utah Lake became so small that the Jordan and Salt Lake City Canal was unable to furnish the irrigators an amount of water equal to what the city was receiving from the creek. Before the crisis came the city claimed the return seepage and spring water which has been referred to, and now proposed to measure to the irrigators the water which they were already using and had always used from the time of its appearance, and which rightfully belonged to them in exchange for the water it was taking from the creek. The owners of the creek water now asked their agent to enforce the contract and retake the creek water. This he attempted, but was resisted by the police authorities of the city. Then came between the parties interested that to which the water laws of Utah seem to be so conducive—a legal bout. The plaintiffs in the suit, or the owners of the water of the creek, asked for an injunction restraining the defendant, Salt Lake City, from diverting any of the water of the creek out of its natural channel or in any way preventing it from running down its natural channel, and that $2,200 attorney fees and $5,000 damages be granted. The case was heard without delay and the prayer granted. Soon after the injunction was granted the pumping plant which pumps the water of Utah Lake into Jordan River was put into operation. The city is not interested in this plant, but made arrangements to receive a good supply for the remainder of the season. Conditions were again such that the city could furnish canal water to the irrigators, so, in accordance with the contract, it took the water of the creek again. But for the fact that the owners of the pumping plant were willing to furnish the water, the city would have been unable to deliver it, and the contract would have become permanently null at the expiration of six months, and the city would thus have been cut off from one of its chief sources of pure-water supply. For the efforts the city has made in trying to increase the natural flow of the stream by swamping the flood waters, protecting the growth of timber, and reducing to a minimum the pollution of the stream by stock, it ought to be commended. But if the mayor of Salt Lake City had acted with its council and aided in the construction of the pumping plant instead of resisting every movement in its favor, the present difficulty

could have been avoided and thousands of dollars might have been earned under the other canals, which this year depended on the plant.

With a view to storing the surplus water of the stream the city claimed, November 12, 1901, all the surplus water of the creek to the extent of 100 cubic feet per second. Four days afterwards Charles Cresman et al. filed on all of the unappropriated waters of the creek, which they intend to divert near the mouth of the canyon and run onto the bench south of its mouth for irrigation purposes. The ditch is constructed and part of the water appropriated was used last season.

From what has been presented it can be seen that the conditions on this stream are becoming complicated. The original owners of the primary rights in the canyon irrigated to produce chiefly hay and grain, and therefore did not want the water very much after the middle of August. The irrigators in the valley had the benefit of it for the rest of the season and also were benefited by the early irrigation, which is now supplanted by swamping. At present the city swamps the water until about August 1, and then transfers it to the conduit. As has been stated, the city claims that the flow has been increased by their practice of swamping, but just how much of the increase it will be entitled to for this reason will be a difficult matter to determine. Again, if the city constructs the reservoir now contemplated it will still further complicate the problem, inasmuch as it will be owned and controlled apart from the creek, while it is intended to use the latter as a carrier from the reservoir to the conduit. Taking everything into consideration, unless the laws of Utah are materially changed, it seems that Salt Lake City and the owners of the creek will be involved in endless litigation.

The following table shows four-fifths of the maximum, minimum, and average discharge in gallons per day, which was the quantity of water received by Salt Lake City from Parleys Canyon Creek:

Four-fifths of the maximum, minimum, and average discharge of Parleys Canyon Creek, in gallons per 24 hours, from November 1, 1901, to October 31, 1902.

Month.	Maximum.	Minimum.	Average.	Month.	Maximum.	Minimum.	Average.
1901.				1902—Cont'd.			
November	5,904,822	3,900,368	4,245,390	April	25,429,248	3,462,912	14,365,210
December	6,889,882	1,555,200	3,987,150	May			
				June	19,671,552	9,593,856	12,509,338
1902.				July	8,729,856	5,375,464	6,941,722
January	4,717,440	1,114,906	3,649,536	August	6,893,984	2,695,680	5,500,570
February	4,795,546	1,736,986	3,825,792	September	5,791,214	3,637,785	3,913,574
March	5,479,141	2,674,944	3,810,586	October	4,007,232	3,612,480	3,784,320

The following table gives the maximum, minimum, and average amount of water, in gallons per twenty-four hours, furnished to Salt Lake City from City, Emigration Canyon, and Parleys Canyon creeks:

The maximum, minimum, and average amount of water, in gallons per twenty-four hours, received by Salt Lake City from City, Emigration Canyon, and Parleys Canyon creeks from November 1, 1901, to October 31, 1902.

Month.	Maximum.	Minimum.	Average.	Month.	Maximum.	Minimum.	Average.
1901.				1902—Cont'd.			
November	12,839,570	10,041,280	10,760,910	April	50,378,208	9,769,344	28,696,629
December	13,565,630	7,127,232	10,007,614	May	45,771,322	17,449,440	28,357,728
				June	49,127,672	23,076,374	33,427,578
1902.				July	22,749,216	14,197,136	17,893,882
January	10,891,680	5,641,498	9,296,608	August	15,680,384	9,306,240	13,312,090
February	10,708,916	5,828,986	9,232,664	September	12,559,886	9,773,145	10,251,974
March	11,975,021	8,361,416	9,516,538	October	10,272,192	9,698,590	9,941,280

MILL CREEK.

Mill Creek rises directly south of the head of Parleys Canyon Creek. For about 11 miles it flows almost due west through the mountains. Through about two-thirds of this distance it is fed by a number of little streams coming from the side canyons. Although the canyon through which this stream flows is adjacent to Parleys Canyon, its natural features are very unlike those of the former. It is very narrow and deep, with perpendicular cliffs and numerous coves, ravines, and side canyons, which afford excellent protection to the snow. The side canyons, even those leading toward the north, are reasonably well protected. The vegetation is of the same kinds as on the areas already described. Toward the mouth of the canyon the growth is scanty, and consists of scrub oak and sagebrush on the sides of the canyon, and maple and birch along the stream. Higher up the oak is partially replaced by maple and birch, while pine and quaking asp predominate near the head. Although the growth of timber is not dense, it serves not only as a protection to the snow, but also to keep in place the soil which retains the water for a time and prevents an early run off. As a whole, owing to its topography and vegetation, the 21.29 square miles drained by Mill Creek is well adapted to act as a regulator of its flow. The accompanying table shows the average daily discharge of the stream, in cubic feet per second, from November 1, 1901, to October 31, 1902:

Average monthly discharge of Mill Creek from November, 1901, to October, 1902.

Month.	Cubic feet per second.	Month.	Cubic feet per second.
1901.		1902—Continued.	
November	13.41	April	15.24
December	12.23	May	29.89
		June	27.36
1902.		July	16.66
January	11.12	August	13.02
February	10.64	September	11.28
March	11.59	October	11.59

The average daily flow is least for the month of January and greatest for the month of May, the latter flow being nearly three times the former. The ratio of the maximum to the minimum flow of City Creek is 6 to 1, while on Emigration Canyon Creek it is 19 to 1. This copmarison shows that the Mill Creek drainage area is a very efficient natural reservoir, in spite of the fact that it is used for grazing.

After leaving the mountains the stream flows through its old delta in a valley-like gorge whose low banks are about one-half mile apart. This gorge continues from the mouth of the canyon westward for a distance of about 1½ miles, when it gradually widens and loses itself in the broad expanse below.

The soil in the gorge is a sandy loam containing some fine gravel. That on the sides is coarser in nature, some of it presenting the appearance of coarse gravel. From the lower end of the gorge the soil gradually changes from sandy loam mixed with fine gravel to a black clayey soil in the upper part of what has been called in this discussion the middle lands. The lower part of the middle lands and the bottom lands are not irrigated by the waters of Mill Creek, except by return seepage and spring water, as will be explained. On either side of the gorge near the mountains is a considerable area susceptible of irrigation from this stream, but the present water supply will not permit of its reclamation. Almost all of the irrigated area is admirably adapted to the production of fruits, and especially is this so of that in the bottom of the gorge, on both sides of it, and for a mile below its lower end. For this reason the water of the stream is very valuable and should be used economically.

Irrigation on this stream began in 1848. The first ditch was constructed near the mouth of the canyon, and is known as the Stillman-Russell Ditch. In the same year, or early in 1849, the Casper, Gardner, Kellar, Hoagland, and Brigham Young ditches were constructed. The Casper Ditch irrigated land on the south side of the creek, but was soon abandoned. The Gardner Ditch is now known as the Murphy Ditch. Other ditches were constructed and used for a time and the rights of some of the first ditches were transferred to new ones. The only lesson to be learned from the records and the evidence furnished by the older inhabitants is that the rights were undefined and the conditions from which crystallized rights could come did not prevail until after 1853. At that time Brigham Young took all the water that was running past Neff's Mill Pond across the bench to Parleys Canyon Creek through a ditch already partially constructed, now known as the Brigham Young Ditch, for purposes mentioned in the discussion of Parleys Canyon Creek.[a] About the same time some of the other

[a] This was agreed to on the condition that the people who had ditches lower down the creek should be furnished with water from Big Cottonwood Creek, and this condition was in part fulfilled.

claimants on the lower end of the Stillman-Russell Ditch abandoned their rights in it and made new ditches which headed just above Neff's Mill Pond. These ditches irrigated the land that is now irrigated and are probably the ones that are now called the F. & G. Neff and A. & J. Neff ditches, although no record of them could be found. In the same year more ditches were taken out near the mouth of the canyon, and the present rights, with the exception of the right of the Stillman-Russell Ditch, are based on these appropriations. This chaotic condition existed without material change until 1876, when Brigham Young relinquished his claim to the waters of Mill Creek.

The people who had appropriated this water nineteen years previously now claimed and began using it, notwithstanding the fact that part of the land originally covered by it had a right to water from Big Cottonwood Creek. Those interested on the stream who were not favored with two water rights were anxious to get a larger supply for a more thorough cultivation of their land or for the reclamation of new land, and therefore did not look upon the action as one of justice and resented the claim of the first appropriators. So, from 1876 to 1880 strife and turmoil existed between the claimants, although no legal action was taken. In 1880 the water commissioners, acting under the law of that year, adjudicated the rights or, rather, arbitrated the differences between the contending factions. The normal flow of the streams at the highest point of diversion was, for convenience, divided into 60 parts, each of which was called a share and supposed to furnish water for 34 acres of land. The result of the arbitration is shown by the accompanying table:

Result of the adjudication of Mill Creek in 1880.

Class.	Ditch or ditches comprising the classes.	Acres.	Shares in the creek.	Acres of secondary right.
I	Bryan Ditch	8.50	1.00	2.50
	James Russell No. 2	2.00		....
	Valorin Russell	8.00		....
	Charles Stillman	14.50		13.00
II	Russell & Moses	27.75	.89	....
	Valorin Russell No. 3	1.00		
	Hussey	1.50		
III	Valorin Russell No 2	45.00	1.66	25.00
	Skidmore-Osguthrope	11.25		
IV	Moses	35.00	1.31	....
V	F. Neff	7.00	2.71	5.00
	J. Neff	25.00		....
	F. & J. Neff	60.00		28.00
VI	Amos Neff No. 1	15.00	5.00	....
	Amos Neff	151.00		22.00
VII	Brigham Young	382.00	11.24	21.50
VIII	Kellar	144.25	4.24	20.00
IX	Hoagland	796.50	23.43	110.50
X	Murphy	282.66	8.31	13.25
XI	White	21.00	.61	233.00
	Total	2,038.91	60.40	493.75

The total number of shares allotted to the ditches is 60.40, when only 60 shares should have been awarded. The error was made in

the allotment to Classes IV and VI, which should have received 1.03 and 4.88 shares, respectively, instead of the number shown by the table. Primary rights for 2,038.91 acres and secondary rights for 493.75 acres were granted. The result of the adjudications was not looked upon with favor by the inhabitants of Upper Mill Creek.[a] The people of Lower Mill Creek received 32.35 parts of the sixty in the creek and had land in proportion to the shares granted, but it was clayey in nature and consequently more retentive of moisture than the gravelly land of Upper Mill Creek. Besides this a large portion of land in Lower Mill Creek had a water right from Big Cottonwood Creek. Although the rights of the stream had been lawfully adjudicated[b] and no appeal from the decision of the water commissioners was made as is provided for in the law of 1880, the decision was not considered just and was not complied with by the inhabitants of Upper Mill Creek; therefore considerable trouble was experienced between them and the inhabitants of Lower Mill Creek until 1882. At that time the people of Lower Mill Creek, for the sake of a peaceable settlement of the rights of the stream, signed a contract with those of Upper Mill Creek, by the terms of which each community was to receive one-half of the creek, or 30 shares. It was agreed that Upper Mill Creek should receive its water as usual at the various places of diversion and that the measurements should be made at those places; that Lower Mill Creek's 30 shares should be measured just below the point where the Brigham Young Ditch heads, and that each party should share equally in the expense incurred in the proper division of the water. So, in accordance with the contract and with a view to obtaining a just division of the water, a system of dividing head gates was installed. The sill of the head gate at the highest point of diversion was made 150 inches long, and as it was level and the water discharged over it everywhere equal in depth, each of the 60 shares occupied 2½ inches of the sill. The upper ditch was entitled to 6 shares, or one-tenth of the stream, so the water running over 15 inches of the sill was diverted by this ditch. The sill of the next diverting head gate was 15 inches less in length than the first and the diverting ditch at this place took 2½ inches on the sill for each of its shares in the creek. In this way the scheme of division was continued, each ditch taking a length on the sill proportional to its share in the creek, the sum of the lengths of the diverting sills being 150 inches.

In devising this system it was assumed that there was no loss or gain by seepage and evaporation, and that the water would be the

[a] The part irrigated by water diverted by the Brigham Young Ditch and those above it is known as Upper Mill Creek and that part irrigated by the ditches below it is known as Lower Mill Creek.

[b] The validity of the law was questioned by the legal profession, but was never tested by a court of final resort.

same in depth on all the sills. But there is a great loss by seepage, as will be shown. Again, the conditions affecting the velocity of approach were not made uniform, and had they been they would have been deranged by the sediment carried by the flood water. As a result of these defects the system was a failure, so far as an accurate division is concerned, but has nevertheless been used until the present time.

Since 1882 the principal difficulty has been the proper division of the water rather than a dispute over the rights, although the latter are not entirely settled. The rights for irrigating have remained the same, so far as the respective rights of the two districts are concerned, although several transfers of right have been made from one ditch to another in Upper Mill Creek, which accounts for the present distribution of rights among the ditches. At present the Bryan Ditch, which irrigates land on both sides of the creek, the Stillman and Stillman-Russell ditches on the south side, and the Skidmore-Osguthrope and Tripp ditches on the north side together own 6 shares, or one-tenth of the stream. The same system of rotation of turns is employed by these ditches as by the individual irrigators on larger ones. The F. & J. Neff or Morris Ditch, the A. & J. Neff, the Kellar, and the Brigham Young ditches have, respectively, 2.70, 3.50, 4.25, and 13.59 shares of the creek running continuously; and Lower Mill Creek is entitled to 30 shares. The water received by Lower Mill Creek is divided among the White, Murphy, and Hoagland ditches. By the adjudication of 1880 the White Ditch was given 21 acres of primary right and 233 acres of secondary right. Because of the leniency of the water masters it has received a varying supply, but always more than 21 acres of right. As a consequence it is now contending for about 200 acres of primary rights. The water remaining in the creek below the White Ditch is divided between the Murphy and Hoagland ditches in proportion to the land irrigated by them. There is but one ditch which claims a surplus right only, although all of them claim the right to use surplus water. This ditch was constructed in 1885, and is known as the Crismon-Russell Ditch.

In addition to the rights for irrigation named above, the Bryan, Stillman, Stillman-Russell, and Skidmore-Osguthrope ditches claim small streams for culinary purposes. These streams run continuously and often exceed in size the irrigating streams in Lower Mill Creek. It is claimed by some of these parties that the grants were made by the water commissioners in 1880, but the people below these ditches say that a condition was imposed, viz, that the water not used for culinary purposes should be returned to the stream. This is not done, but it is used for irrigation. The culinary stream problem has become one of moment, inasmuch as the streams are larger than when first taken and other parties are now claiming similar rights. This, together with the unsatisfactory division, has led the people into what

is termed a friendly lawsuit or another arbitration, which is now pending.

At and below the stage of the creek when its cross section at the highest point of diversion is 900 square inches, only primary rights are recognized. Between this stage and when its cross section is 1,300 square inches the primary and secondary rights are satisfied. Above the latter stage the surplus ditches are allowed a portion of the stream. A statement of these stages has never been embodied in any written agreement or expressed in any unit of flow. In determining these stages no attention is given to the velocity of approach which must change with its discharge and with the condition of its bed above and below the place of measurement. Current meter measurements at the primary and surplus stages show 17.86 and 33.09 cubic feet per second, respectively. As soon as the stream reaches the stage when its cross section is slightly above 900 square inches, e. g., 950 square inches, the head gates of all the ditches that run constantly, with the exception of Lower Mill Creek, are widened in proportion to the number of acres of secondary right owned by each and those ditches that run alternately are allowed a longer time for each turn. The flow of the stream is soon reduced below its primary stage, but the upper ditches continue to keep their head gates widened, even though the lower ditches are getting less than their share of the normal discharge. This condition is true even when the creek is nearing the surplus stage. The system of obtaining the secondary right has been described by a disinterested party as "simply a licensed theft of water." When the surplus stage is reached, the Crismon-Russell and Skidmore-Osguthrope ditches run continuously and take streams the size of which is determined by the capacity of the ditches or the judgment of their owners.

In Utah, in a section where land and water are very valuable, and within a half score of miles of where modern irrigation was first tried, these conditions still exist. The State has neither provided a code of laws adapted to solve its peculiar problems nor copied less efficient laws from the codes of neighboring arid States now farther advanced in irrigation legislation.

The only possible good that can accrue from the contemplated lawsuit is to have the size and number of the culinary streams determined. The primary and secondary rights have already been established, and so far as can be learned will not be contested. The only remaining problem is the just distribution of the water, a problem in engineering rather than in law. At the mouth of the canyon, the principal difficulty has been in changing the irrigating stream from one ditch to another. To obviate this, and the physical conditions will permit it, all the ditches on either side of the creek could be combined in one, so that there would be only two ditches at the mouth of the canyon. A proper division could be effected by placing in the stream three Cippoletti weirs mounted on the same framework and having their crests

on the same level, one with a crest 120 inches long and one on either side with a crest 15 inches in length. These could run constantly; and the culinary streams, whatever the size might be, could be provided for by means of spill boxes below the diverting weirs, so that when either of the ditches was not entitled to water for irrigation the spill boxes would still divert the culinary streams. In like manner since the F. & J. Neff, A. & J. Neff, and Kellar ditches parallel each other for considerable distances they could take their combined flow in one ditch with advantage. The division could be made in the same way as explained above, except that two weirs with their crests proportional to the amount to be diverted and the amount to remain in the stream would be used. In the same way the remaining division between Lower Mill Creek and the Brigham Young Ditch could be made. The weirs could be made adjustable to provide for the distribution of the secondary rights and provided with sluice gates to remove the sediment that would be deposited in front of them. Besides making the problem of distribution more simple this arrangement would reduce the amount of water lost by seepage and evaporation and save for cultivation some of the area occupied by the ditches.

If more extended improvements are desired, the saving of loss by seepage presents a profitable field. The seepage measurements show that over 2.5 cubic feet per second is lost between the mouth of the canyon and Neff's Mill Pond, a distance of about 2 miles. A rock-lined open conduit large enough to carry the flow of the stream could be constructed at a nominal cost, probably $2,000 in labor and $500 in cash per mile, and would likely save over 2 cubic feet per second of the loss. The duty of water on similar soil is about 60 acres per cubic foot per second. So at least 100 acres of land now worth $50 per acre would be increased in value to $200 per acre by more thorough watering. Land in this section can be made to produce from $300 to $500 per acre. At an increase of $300 per acre a total increase in production of $30,000 per year would result, as well as the increase in the valuation of the land, if the loss could be prevented and the water used intelligently.

Owing to the comparatively uniform flow of the stream, the great slope of its bed, and other natural features, it is well fitted to generate power on a small scale. With this purpose in view several claims have been filed. Since 1849 the stream has furnished power for several lumber and shingle mills, two of which are still in operation.

From the heads of the Murphy and Hoagland ditches for 1½ miles down the old stream bed no water from Mill Creek is found at any time of the year. But below this numerous springs rise in the old creek bed and the drainage from the surrounding country comes into the stream. In less than a mile about 18 cubic feet per second finds its way into the channel. Part of this flow is diverted to irrigate orchards, pastures, and hay lands which are situated above the Wasatch

roller mills. The mill is furnished with power by the stream, after which the water is used for irrigation. The land irrigated produces chiefly pasturage and hay, although various crops are grown under the Harmon Ditch. Measurements were made August 18, 1902, of the amounts diverted by the ditches, and Upper Church Ditch was found to carry 1.61 cubic feet per second; Lower Church Ditch, 2.50; Harmon Ditch, 3.03; and Cannon or Riverside Canal, 7.87 cubic feet per second, respectively, while 2.76 cubic feet per second was discharged into Jordan River.

The ditches interested take what water they want and when they want it. There seems to be enough water for all, and as a consequence their rights are not determined in any way.

SEEPAGE MEASUREMENTS.

The result of the seepage measurements on Mill Creek in September, 1902, are shown by the accompanying table. The measurements were made by the aid of Cippoletti weirs and the current meter. The points selected for the gagings were designated as stations 1, 2, and 3. These stations were selected with the object of obtaining accurate gagings, and Station 2 was located so as to divide the creek into two sections, one of which was thought to lose a large percentage, while there was a doubt as to whether the loss in the other was significant. Station 1 is situated just above the Cippoletti weir maintained by the engineering department of Salt Lake City, near the mouth of the canyon. Current meter measurements were made at this station because the weir does not fulfill the requirements of an accurate measuring device. Station 2 is situated in the creek bed just below Neff's Mill Pond, the place where Lower Mill Creek's water is measured. Station 3 is located just above the heading of the Murphy and Hoagland ditches. The diversions in both sections were measured at the heads of the various ditches.

Seepage measurements made on Mill Creek, Salt Lake County, Utah, September, 1902.

FIRST SECTION.

Inflow: Creek at Station 1	cubic feet per second		11.24
Outflow:			
Bryan	cubic feet per second	0.20	
Skidmore-Osguthrope	do	.22	
Stillman	do	.30	
Stillman-Russell	do	.94	
Morris	do	.39	
Neff	do	.43	
Brigham Young	do	1.94	
Kellar	do	.38	
Creek at Station 2	do	3.88	
			8.68
Loss in section	cubic feet per second		2.56
Length of section	miles		2
Loss per mile	cubic feet per second		1.28
Percentage of loss	per cent		22.7

SECOND SECTION.

Inflow: Creek at Station 2	cubic feet per second..		3.88
Outflow:			
Diversions	cubic feet per second..	0.70	
Creek at Station 3	do....	3.04	
			3.74
Loss in section	cubic feet per second..		.14
Length of section	mile..		.75
Loss per mile	cubic feet per second..		.19
Percentage of loss	per cent..		3.6

NEFFS CANYON CREEK.

Neffs Canyon Creek rises and has its entire drainage area on the face of the mountains about 1 mile south of Mill Creek Canyon. The canyon is steep and rough and its sides are precipitous. From its mouth it leads southeast, and from a topographical point of view is well adapted to protect the snow and poorly fitted to retain the water resulting from it. There is very little soil on the upper part of the drainage area owing to the great inclination of the face of the mountains, and consequently the growth of timber is not heavy. Lower down there is more soil, but it is protected only by sagebrush, scrub oak, birch, and maple. Although it has some good natural features, the area is but poorly fitted to provide a constant flow of water. As a result, the stream runs from April until about the 1st of July. No measurements of the stream were made, but it probably discharges from 1 cubic foot per second in early April to 15 or 20 cubic feet per second in June, and then gradually diminishes until the first part of July, when nothing is left but spring water, which comes into the canyon near its mouth. Below the mouth of the canyon the soil is composed of coarse gravel and stones, and is therefore unfit for agriculture without considerable labor; so the water is taken below this tract and used on the lower part of the bench lands. The principal crop grown is alfalfa, and there is usually sufficient water to irrigate about 500 acres of it two or three times, enabling the farmers to get one good crop and part of another one when care is taken to irrigate the land properly.

There are two classes of rights to the waters of Neffs Canyon Creek, viz, the right to the constant flow of the springs alluded to above and the flood-water rights. The rights to the use of the flood water present nothing of particular value; therefore a discussion of them will be omitted except to say that they were adjudicated by the water commissioners in 1880, and this decision was final. Neither is there anything uncommon regarding the right to the spring water, but it is the way in which the springs were made useful that is of interest and value. Mr. A. V. Taylor, attorney, of Salt Lake City, appropriated the springs, whose flow was being wasted, and developed

them until their total flow reached about 2 cubic feet per second. A tract of land near the mouth of the canyon was purchased from the State at $2.50 per acre. The stones were cleared from 100 acres at a cost of about $50 per acre. The water was then piped from the springs to the land, a distance of about 1 mile, at an expense of $2,250, including the development of the springs. The water now irrigates the 100 acres of land, which have, besides alfalfa and general crops, an orchard of 3,000 trees.

Land in this vicinity is worth $200 per acre, so the whole property, including the water, is probably worth $20,000. Mr. Taylor estimates that the orchard alone when in full bearing will return between $4,000 and $5,000 per year. These facts speak of the value of water in this section and of the need of a comprehensive code of laws regulating its appropriation and use.

BIG COTTONWOOD CREEK.

Big Cottonwood Creek is the largest and most important of the streams tributary to the Jordan River. Like the other streams, it rises in the summits of the Wasatch Range, but, unlike them, its head tributaries are the outlets of a number of small lakes, among the most important of which are Lake Mary, the Twin, Silver, and Dog lakes. The head of the creek is distant from the mouth of the canyon about 14 miles, and its general direction of flow is west, although the upper part of its course bears northwest and the lower part southwest. The creek is fed also by numerous little streams which come from the side canyons. It drains an area of 48.47 square miles.

The canyon is deep, its sides are high and steep, and its fall is great for about one-half of its length. The side canyons leading from it, with their cliffs, coves, and ravines, are similar to the main canyon. The upper part of the canyon is broader, its sides more receding and rolling. At the head of the canyon where the lakes lie is a small basin-like valley, bounded on the north and south by the dividing ridges and on the east by the backbone of the Wasatch Range. The vegetation on the area is fairly abundant. The higher portions are mostly covered with a growth of quaking asp, pine, and dense underbrush. The lower part is protected by some pine, maple, birch, cedar, scrub oak, and a less dense undergrowth. The area is well covered with soil, and usually receives a heavy fall of snow, which during some seasons reaches a depth of from 12 to 16 feet near the lakes and the dividing ridges. As a whole, the area is well adapted to protect the snow and retain the resulting water and the rainfall until it can be used for irrigation.

After leaving the mountains the stream takes a northwesterly course for a distance of about 9 miles, and then empties into the Jordan River. All the irrigable lands in Salt Lake County east of the Jordan

are susceptible of irrigation from Big Cottonwood Creek. On the north side of the stream bed it irrigates a tract from the mouth of the canyon to the river, which varies in width from 1.5 miles near the river to 3.5 miles in the widest place, narrowing again to 0.5 mile at the mouth of the canyon. This tract includes bench, bottom, and middle lands. There is also irrigated from it a tract on the south side extending 4 miles from the mouth of the canyon and varying in width from 0.5 mile near the mouth to 2.5 miles near the lower end of it. It embraces but bench and middle lands, although there is considerable low and swampy land in it. The total acreage claimed by all the ditches diverting water from the creek is about 9,000 acres.

The accompanying table shows the total monthly flow in acre-feet from November 1, 1901, to October 31, 1902.

Average monthly flow of Big Cottonwood Creek from November, 1901, to October, 1902.

Month.	Acre-feet.	Month.	Acre-feet.
1901.		1902—Continued.	
November	1,663.94	May	12,620.41
December	1,649.39	June	11,597.04
		July	3,815.89
1902.		August	2,010.48
January	1,434.75	September	1,584.87
February	1,336.11	October	1,585.47
March	1,513.66		
April	4,232.53	Total	45,044.01

The measurements were taken over two 15-foot Cippoletti weirs, which at no stage of the creek gave accurate results. All the measurements until August, at which time the detritus in front of the weirs was removed, were appreciably affected by the velocity of approach and especially was this true during April, May, June, and July. From November until April the discharge was determined as on the other streams by daily readings; after this time a water register was used and the discharge calculated from its records. It is probable that the total discharge in acre-feet as shown by the table is 10 to 15 per cent less than was actually discharged over the weir during the time covered by the table.[a] Reference to the table will show that the average flow is least in January and greatest in May, and that the latter discharge is nearly nine times the former. On Mill Creek the greatest and least discharges occur in the same months, but the maximum is less than three times the minimum. This, together with the fact that Mill Creek discharges remarkably well in the late summer, points to the conclusion that the Big Cottonwood Creek area is not as efficient a natural reservoir as that of the former stream. This is true with respect to the total precipitation and run off, but a comparison of

[a] To the amount shown by the table should be added that diverted by the Butler Ditch, it being taken out above the weir, but its supply is small and a record of it was not kept.

the areas and discharges of the streams in August, when water is most valuable and the flow is likely to be low, will show that the Big Cottonwood Creek area is 2.2 times that of Mill Creek and that the average daily discharge of the former is 2.5 times that of the latter.

The water rights in Big Cottonwood Creek, while still unsettled, are not very complicated; the problem of distribution is simple, the concessions to be made in order to effect a peaceable adjudication are few, and great benefits would be derived from a determination and consolidation of the claims to water. Of the ditches now diverting water from Big Cottonwood Creek the Upper Canal and the Tanner, Newman, Green, and Big ditches claim to have commenced construction work in 1848, and each claims the distinction of having been the first to begin work. From the available evidence it seems that the claim of the Upper Canal is just, affidavits from its superintendent of construction and several of the older inhabitants to that effect being matters of record. It is probable, however, that both the Tanner and Green ditches were earlier in diverting water from the creek. Under the laws of Utah all recognized primary rights are equal, and during times of scarcity the supply is prorated, so that the date of appropriation would seem immaterial so long as those interested are owners of primary rights. But it has been entered as evidence in at least one lawsuit and so it seems to be considered of some importance. At present the law provides that a notice of appropriation posted at the point of intended diversion fixes the date and consequently the priority of the right, provided there are no unnecessary delays in the prosecution of the construction work. In 1848 Utah had no water laws, but it would seem that the promoters of the Upper Canal served notice upon the public of their intention to divert water from the creek when they began the construction work of their canal. It would appear that this canal was the first appropriator, notwithstanding the fact that it did not divert the water as soon as some of the rest of the ditches. In 1852 all these ditches were diverting water for irrigation, but none took the volume that they now divert. In some cases the places of diversion have been changed and the ditches have been enlarged to meet the demands of land reclaimed later. Other diversions were made, including the Lower Canal, Farr & Harper, Brown & Sanford, Hill, and Butler ditches were taken out and new lands continued to be reclaimed until 1874, when the greater part of the normal flow of the stream had been appropriated. This is inferred from the fact that a special committee from the Salt Lake City council presented a petition September 29, 1874, to the county court, asking for the use and control of about one-third of Big Cottonwood Creek to supply the southeast portion of the city. However, the court was of the opinion that the petition could not be granted without infringing upon the rights of those who had appropriated the water for irrigation. The ditches

taken out later were enlarged and new lands brought under cultivation, so that by these accumulative appropriations some of the latest land reclaimed lies under the ditches which made the first use of water.

THE ARBITRATION OF 1879.

In 1879 there was a general demand for a settlement of the rights to the water of the stream, and arbitration was decided on: so, in September, 1879, the people chose a board of arbitrators consisting of Joseph S. Rawlins, Reuben Miller, and D. B. Brinton. These men were then appointed by the district court to adjust all claims and report their findings. For convenience they divided the flow at the highest point of diversion into 60 parts, each part or share to be the allotment for use on 127.25 acres. To obtain the facts from which to make their decision the board of arbitration called the owners before them to state under oath the number of acres of land they had irrigated in the past. No measurements of land or water were made, nor was the difference in soils taken into consideration, but each ditch was awarded a number of shares in the creek in proportion to the number of acres that it had irrigated. It is said that under some of the ditches a greater number of acres were entered than were irrigated, while under others not enough were reported, and that some land requiring little or no water received its pro rata of shares in the creek.

A report of the findings of the board was made to the district court and properly filed. The primary rights only were arbitrated and every owner of such received a written notice of the arbitration. A time was set by the court for hearing objections, but no one appeared and the judgment of the court was made in accordance with the terms of the arbitration. Most of the owners of primary water rights had signed an agreement under oath to accept the division made by the board as final and binding. There were a few who would not sign this agreement, among whom were the Walker Brothers, owners of what is now known as the Walker Ditch, and a few of those interested in the Green Ditch. This agreement was filed with the district court, but at present can not be found. The men constituting the board of arbitration were intelligent farmers, and though their knowledge of irrigation was limited they were thoroughly conversant with the conditions at that time, and so it is probable that the decision was fairer and less expensive than could have been obtained from the courts. In the light of the knowledge of to-day their methods would be severely criticised. If their decision were now strictly followed the injustice of it would be apparent, but twenty years has effected great changes in the lower land, it requiring less water now than formerly. Whether or not it was just then, the fact is that a readjustment is needed now if the section susceptible of irrigation from the creek is to receive the greatest

possible development. The following table gives the division made by the arbiters:

The distribution of Big Cottonwood Creek as made by the board of arbitration in 1879.

Class.	Ditch.	Number of shares. Jan. 1 to July 1.	July 1 to Jan. 1.	Class.	Ditch.	Number of shares. Jan. 1 to July 1.	July 1 to Jan. 1.
1	Butler Ditch	0.5	0.2	6	Farr & Harper Ditch	0.6	0.6
2	Brown & Sanford Ditch	4.5	2.1	7	Lower Canal	5.6	6.1
3	Upper Canal	10.5	10.2	8	Big Ditch	19.6	21.3
4	Tanner Ditch	12.6	12.9	9	Hill Ditch	2.6	2.8
5	Green Ditch	3.5	3.8		Total	60.0	60.0

From 1879 until recently the arbitration has furnished the basis upon which the water has been divided, although the owners of the Green Ditch seldom concurred or aided in the division, but took what they wanted from the creek. Some of those interested in the Tanner Ditch now say that it has never been strictly abided by and that they have always had more than was allotted to them. As a consequence, the Tanner Ditch is now claiming the right to what they suppose they have always received. The fact of the matter is that the upper ditches have always had more than their allotment and the lower ones less. This has been due partly to the leniency of the owners of the lower ditches and partly to the inaccuracy of the measurements. The owners of the water rights in each ditch annually elected a water master whose duty it was, among other things, to help those elected from the other companies in dividing the water of the creek. In the early part of the irrigating season when the creek began to rise the upper ditches took what they wanted, and as long as the lower ditches had plenty no objection was made, but as soon as the stream began to recede the irrigators above were compelled to restrict the volume they diverted. Later in the season the water masters were called upon to make a division. They would meet at the lowest point of diversion on the creek and proceed to the highest, measuring the cross section of each irrigating stream in square inches at its head gates. The sum of the cross sections in square inches represented the flow of the stream available for diversion and was divided by 60 to get the number of square inches to which each share in the creek was entitled. The allotment, in square inches of cross section, was then made to each ditch in proportion to the number of its shares and the flow of the stream was divided among the ditches in accordance with the allotment made, proceeding from the highest to the lowest point of diversion. No attention was paid to the velocity of approach nor was any well-designed attempt made to make it uniform. The upper ditches took the quantities allotted and the lower ones received what was left. The divisions were repeated from time to time as the creek receded

or needed regulation from any cause whatever. One feature of this way of dividing a stream is noticeable and commendable; that is, that the sum of the diversions rather than its discharge at the highest place of diversion was taken to be the flow of the stream. In this way each ditch stands its share of the loss or gain by seepage.

This method of division was continued without legal interruption until 1891, when the arbitration was contested by the owners of Green Ditch. This ditch was the only one that asked for a readjustment of right; it received judgment for enough water to irrigate 400 acres of land Under this judgment, until 1901, the Green Ditch took all the water its owners wanted, at times maintaining a solid dam across the creek. During this time the Big Ditch and Lower Canal were forced to remove the dam from the creek, notwithstanding the decree in favor of the Green Ditch, or lose their crops; in fact no attention has been paid to the decree by the other ditch owners, inasmuch as the amount of water necessary to irrigate 400 acres of land was not defined.

Since the arbitration two other small ditches—the Newman Ditch and the Ellison Ditch—have been allowed a portion of the primary water, and through the leniency of the primary owners and the continued use of the water by them they have obtained rights that are now recognized by the most of the primary owners. The Walker Ditch is now diverted from the Green Ditch above the point where the latter is measured and is therefore an independent ditch. It was not known in the arbitration under its present name, as its right at that time was included in the Green Ditch, although it is said to have one of the oldest rights on the creek.

In 1884 the Brown & Sanford Ditch asserted its claim to one-fifteenth of the creek, or four shares, but the division was made subsequently in accordance with the arbitration, notwithstanding their claim. There was, however, a feeling of uneasiness pervading the entire system, and especially so after the Green Ditch received its decree. The lower ditches received less and less with each succeeding year, and conditions were becoming such as to make decisive steps imperative. In August, 1900, the Big Ditch and Lower Canal companies, aided financially by some of the other ditch owners, entered suit against the Green Ditch Company and asked for a temporary injunction restraining it from taking the water which was claimed below. The injunction was granted, but after a few days' duration was lifted. As the season was about over action was discontinued, but the suit was not withdrawn.

THE READJUSTMENT PROPOSED IN 1901.

Early in the spring of 1901 the Mormon Church authorities endeavored to effect a settlement without litigation and proposed the readjustment shown in the table following. Even individual representative owners of the different ditches could not agree upon a readjustment of

rights which would afterwards be made binding and legal. In the meantime the law of 1901 became operative and a water commissioner was appointed under its provisions. In order to furnish a basis upon which division could be made, all the ditches except the Tanner, the Green, and the Walker, agreed to accept the proposed readjustment of rights as a basis for that season's division. The accompanying table shows the proposed readjustment of the rights which was made the basis of division for the seasons of 1901 and 1902 and also the awards made by the former arbitration.

Proposed readjustment of the rights used as the basis of division for the seasons of 1901 and 1902 and the awards made by the arbitration of 1879.

Name of ditch.	Number of shares.			Name of ditch.	Number of shares.		
	Proposed readjustment.	Jan. 1 to July 1.	July 1 to Jan. 1.		Proposed readjustment.	Jan. 1 to July 1.	July 1 to Jan. 1.
Butler Ditch	0.5	0.5	0.2	Walker Ditch	0.3	0.0	0.0
Brown & Sanford Ditch	3.5	4.5	2.1	Farr & Harper Ditch	.5	.6	.6
Ellison Ditch	.7	.0	.0	Lower Canal	6.0	5.6	6.1
Upper Canal	10.5	10.5	10.2	Big Ditch	17.0	19.6	21.3
Newman Ditch	.2	.0	.0	Hill Ditch	1.9	2.6	2.8
Tanner Ditch	12.9	12.6	12.9				
Green Ditch	6.0	3.5	3.8	Total	60.0	60.0	60.0

A comparison of the first and third columns will show how the adjustments were to be made. Those agreeing to the readjustment were to stand in a suit against those opposing it in case of legal trouble. Notwithstanding the opposition, all the ditches accepted the division as made during the season of 1901. At the beginning of the next season a permanent settlement of the rights seemed impossible, so the creek was again divided as during the previous season, but more difficulty was experienced from the opposition. It began to be whispered about, and even those charged with its enforcement declared, that the arbitration was unconstitutional and that they could not enforce it. This licensed the owners of the Green, Tanner, and Walker ditches to disregard the law and ignore the division made by the water commissioner. Arrests were made, but the county officials, for reasons yet to be explained, neglected to prosecute the offenders. The protection and assistance that the law was intended to give not being received, the suit filed in August, 1900, has recently been so amended that the owners of the Green, Tanner, and Walker ditches are made defendants, and those of the remaining ditches, plaintiffs. The plaintiffs will endeavor to have the terms of the arbitration confirmed, but no matter what decree is given the shares remaining after the judgment for the defendants has been satisfied will be divided in proportion to the shares given to each ditch by the proposed readjustment.

The owners of the Walker Ditch claim the right to take what water

they want at any time they want it. The claim of the Green Ditch has already been alluded to. The irrigators under the Tanner Ditch claim 15 shares instead of 12.9, although they acknowledge that when the water masters made the division it was their intention to divert only the latter amount. But when a more accurate measurement was made, they estimated that they had always received the amount they claim and are now entitled to it. It is predicted by some that if the rights are settled by the court, the final decree will not differ much from the basis of division for the past two seasons. It is said by some of the older inhabitants that the division of the creek was more equitable during the season of 1901 than ever before. Whatever the outcome, it is reasonably certain from past experiences in Utah and other arid States that it would have been more economical and satisfactory had the rights been rearbitrated by disinterested parties having a knowledge of irrigation and water rights, assisted by a legal adviser, before whom all the facts and evidence could be elicited and considered, instead of by a court whose knowledge of irrigation is meager and by whose ruling a considerable portion of the pertinent evidence is always either stricken out or not allowed to be presented.

The division of the creek is effected by means of Cippoletti weirs at convenient places in the ditches, some of which are also provided with head gates. The ditches are small, the maximum discharge of any canal being about 60 cubic feet per second during the flood season. Although the flood waters deposit sediment in front of the weirs, they are used in preference to rating flumes, because the ditches are small and the supply fluctuating. The method of division now used is similar to that employed by the water masters, excepting that the unit used is the cubic foot per second instead of square inches of cross section. The diversions are measured and their sum taken as the flow of the stream. This is divided by the number of shares in the creek to find the amount to which each share is entitled. The allotments are then made and the diversions are regulated in proportion to the shares owned by each ditch. The accompanying table will probably assist in conveying the idea of how the divisions are made. The names of the ditches appear in the table in the order in which they are measured; that is, from the lowest to the highest point of diversion. The amount diverted by the Hill Ditch is not included in the sum of the diversions, as it is supplied entirely from the return seepage water below the dam maintained by the Big Ditch Company, and the measurements show that it was getting 2.9 instead of 1.9 shares. The Farr & Harper Ditch and the Ellison Ditch are entitled to only 0.5 and 0.7 shares, respectively, but these amounts are so small that three times the constant flow allotted to them, or 1.5 and 2.1 shares, are used for one-third of the time. The Newman Ditch makes a like arrangement, but it was dry on the date of this measurement.

Division of Big Cottonwood Creek, July 28, 1902.

Name of ditch.	Diversions.	Allotment.[a]	Shares.	Name of ditch.	Diversions.	Allotment.[a]	Shares.
	Cu. ft. per sec.	Cu. ft. per sec.			Cu. ft. per sec.	Cu. ft. per sec.	
Hill Ditch	1.94	1.27	1.9	Newman Ditch			
Big Ditch	11.74	11.42	17.0	Ellison Ditch	1.66	1.41	2.1
Lower Canal	4.10	4.03	6.0	Upper Canal	7.12	7.05	10.5
Farr & Harper Ditch		1.00	1.5	Brown & Sanford Ditch	2.61	2.35	3.5
Walker Ditch		.20	.3	Butler Ditch	.42	.33	.5
Green Ditch	4.26	4.03	6.0				
Tanner Ditch	8.66	8.67	12.9	Total	40.57	40.49	60.3

[a] The allotment per share is 0.67 cubic foot per second.

The secondary or surplus rights are also in an unsettled state. Besides the primary right owners, the McGhie, Severson, Harper & Taylor, old Tanner or Gunderson, and the old Green ditches are interested in the stream during the flood season. The Harper & Taylor has not been used recently, but its claim is still asserted. The old Tanner and old Green ditches are owned by the present Tanner and Green ditch companies, and are used to increase the amount diverted in the easiest and safest way. There is no established stage of the creek when these ditches are allowed to divert water, or when they are to be closed. In the spring, when the creek begins to rise, these ditches take what they want, and if the primary owners are not supplied with enough water, the ditches for surplus water are shut down. When the stream recedes to such a stage that the lower ditches need more water, the supply of all the surplus ditches is cut off regardless of the dates of their appropriations. This is done before any of the ditches owning primary rights have their streams reduced. At first thought the custom seems right, but a knowledge of the conditions points clearly to its injustice. Attention has already been called to the fact that the older ditches have grown in size step by step, and as the ditches grew more land was reclaimed. This was done even since 1884, when ditches depending on the surplus flow of the stream began to be constructed. The effect of this practice of establishing later rights under the original ditches is the same as taking out new ditches and irrigating newer lands than those irrigated by the ditches depending on the surplus flow. Attempts have been made to establish dates when the surplus ditches would be recognized and when they would be deprived of water. Such an arrangement would be unjust to the primary owners, because the stage when surplus water becomes available does not occur at the same time each year.

The conditions suggest that a stage of the creek measured in cubic feet per second should be established, at which time the rights to surplus water would be recognized. The dates and the amount of the different appropriations of surplus water should be ascertained, so that after the oldest appropriation is satisfied the next oldest one could

divert its shares, and so on, the youngest one being the last to receive its share and the first to be shut down. If the present conditions continue, either the ditches accustomed to take surplus water will lose their rights, or a legal clash between the primary and surplus rights will occur.

CANALS AND DITCHES.

A map accompanying this report shows the location of the canals and ditches diverting water from the creek. Commendable features or needed improvements on the various ditches are noted in the following paragraphs:

The Butler Ditch is the highest one on the creek and irrigates about 160 acres during the flood season. It is taken along the side of the canyon and foothills for about 1.5 miles. As a result the loss by seepage is very great, being about 70 per cent of the small stream diverted. In cleaning the ditch its bottom and sides should be disturbed only so much as is necessary. Puddling the sides and bottom with clay would be a cheap preventive of seepage.

The company controlling the Brown & Sanford Ditch is incorporated, and its business is transacted by a president and board of directors, which is a commendable feature. It irrigates about 1,000 acres of sandy, gravelly bench land. It is estimated that the ditch loses by seepage about 25 per cent of the water diverted, as a result of the loose nature of the soil. As the soil is excellent for the production of fruit the amount of water that could be saved by a pipe line or rock-lined conduit would probably pay the expense of the construction in a short time.

The management of the Upper Canal by its incorporated company is the most progressive of any of the ditches or canals. It is the only one that was surveyed or constructed by an engineer. An accurate division of the water among the laterals taken from it is attempted. Cippoletti weirs are placed below the heads of the laterals and the flow over them is controlled by means of head gates; the water master, who is paid a salary, makes the division each day during the irrigating season. The ditch irrigates about 1,500 acres of sandy, gravelly, and sandy loam soil nearly all of which is well adapted to fruit culture.

The Tanner Ditch Company is not incorporated, its business being transacted principally by its water master, who is elected by the stockholders annually and also instructed by them on the more important questions with which he has to deal. No attempt is made to divide the water accurately among the branches and laterals of the ditch, although the slope of the ditch and its laterals is such as would permit the use of a system of Cippoletti weirs. The upper part of the ditch runs over a loose gravelly formation, and therefore the loss by seepage is considerable. Water is not so valuable in this ditch as in the Upper

Canal, because the crops raised are less valuable, although there is a considerable amount of fruit produced under it. Any improvement intended to save the seepage should be based on careful measurements and estimates.

Generally speaking, the same conditions exist and the same problems are to be dealt with on the Green Ditch as on the Tanner Ditch.

If the owners of the Lower Canal are to receive the greatest good from the water it diverts, a change in the management of its affairs and in the method of division is necessary. In the early part of the season several irrigating streams are taken from the canal. In some cases the banks of the canal are cut to divert the water and the amount taken decided by the judgment of the water master. Later in the season, however, the entire flow of the canal is concentrated into one or two irrigating streams and the problem of diversion is made more simple. Although the slope of the canal itself is moderate, there is sufficient fall in the laterals to permit the use in them of Cippoletti weirs and head gates. On account of the gentle slope the growth of water weeds is abundant. It would be profitable to remove the growth once or twice during the season in order to prevent the excessive waste by seepage and evaporation. The canal has a water master who receives his salary from an assessment made for that purpose, and most of his time is spent in collecting it. The owners have recently incorporated their interests and the officials have an opportunity to make improvements.

The conditions regarding the division of the flow of the Big Ditch are much the same as on the Lower Canal, but the slope is greater, and no trouble is experienced from weeds. A system of more accurate dividing gates could be employed in the ditch to divide the stream between the branches and forks, and a system of weirs and head gates could be installed in the laterals. The ditch company is incorporated, and the management of its affairs is businesslike.

The Ellison, Newman, Walker, Farr & Harper, and Hill ditches are small; and the entire stream in each is used by the owners under the system in rotation or turns, as is the flow in the laterals on the larger ditches.

Simultaneously with the attempt to settle the rights without legal trouble, another was made to incorporate all the interests of the creek, each ditch to take stock in the new company in proportion to the amount of water owned by it. But the unsettled condition of the rights was chief among the obstacles to its consummation. However, in October, 1902, all the ditches excepting the Tanner, Green, and Walker succeeded in effecting an organization and filed articles of incorporation. The capital stock of the company is $240,000, or $4,000 for each share or one-sixtieth of the creek. It is known as the Big Cottonwood Consolidated Irrigation Company and will be con-

trolled by a president and board of directors to be elected by and from those interested in the different ditches. Its purpose is a more economical administration of its affairs and to defend the rights of those interested as well as to effect some improvements. The new company has a wide field.

VALUE OF WATER AND MEANS OF CONSERVING THE SUPPLY.

The seepage measurements made on this stream show that about 7 cubic feet per second is lost between the weir at the mouth of the canyon and a point about 2.5 miles below, near the head of the Green Ditch. An idea of the value of water in this vicinity can be gained from the return through irrigation from a 2-acre peach orchard at the stage of full bearing belonging to Mr. F. McDonald, of Holliday. The soil is a rich sandy loam, not retentive of moisture, but easily kept in a loose and finely divided condition. Until August it was well cultivated and the growth of weeds prevented, but later it was somewhat neglected. The Upper Canal from Big Cottonwood Creek supplies the orchard with water, which was measured over a Cippoletti weir. Although the supply fluctuated a little it was intended that 1 cubic foot per second should be diverted each time and be used for six hours every eight days. Great care was given to the picking and marketing of the crop, and it was found that it returned $800, or $400 per acre. At this rate 1 cubic foot per second flowing continuously during the season would irrigate 64 acres of land. If 6 of the 7 cubic feet per second lost by seepage could be saved, 384 acres of the same kind of land cultivated in a like manner could be irrigated with it. Using $300 per acre instead of $400 as the basis of calculation, the total value of the crop would be $115,200. Unirrigated land or that upon which rye or one crop of alfalfa is produced by one irrigation varies in value from $10 to $75 per acre, while the same land with fruit trees on it is worth from $250 to $500 per acre. Taking the increase in value per acre to be $250, the total increase in value of the land and water is $96,000.

August 30, 1900, Salt Lake City filed a notice of appropriation in which it claimed the right and intention of saving this loss. The scheme by which it was intended to save water proposed a pipe line about 36 inches in diameter or a rock-lined conduit of sufficient size to carry the stream. This was to be constructed in the creek bed to convey to the ditches their respective amounts of the natural flow, and that which was saved was to be taken through a pipe line to the city, a distance of 10 miles. The already complicated condition of the rights and the expense of conveying the amount saved to the city were the chief reasons for abandoning the scheme. But with the new company conditions are quite different. The principal part of the material for a rock-lined conduit is at hand, and most of the labor

could be furnished by those to be benefited during the winter months when there is little to be done on the farm, and, after the saving has been effected, no more expense need be incurred for its diversion and use.

Attention has already been called to the table showing the daily discharge of the stream. The great fluctuation of the discharge together with the value of water naturally suggest storage as a remedy for the insufficient supply. Although most of the flood water is diverted for irrigation, a great quantity finds it way to the Jordan by way of its channel or through the irrigation ditches and canals to waste ditches and thence to the adjacent creeks. That which is used goes on alfalfa or grain fields, it being too early to irrigate any but the small fruits, in such quantities that the crop is often damaged through the farmer's eagerness to use the water when available. The table shows that 44,573.54 acre-feet was discharged over the weir. The total acreage claimed to be under ditches including the surplus ditches is about 9,000 acres. Not more than one-half of this area is irrigated after the flood waters have gone. It is estimated that the average loss in storing water is from 10 to 15 per cent. It is also estimated that the amount shown by the table is less than the total discharge of the stream by fully as large a per cent. on account of the errors of measurement and the amount diverted by the Butler Ditch. The irrigation season in this section usually begins about April 15 and ends about September 20. In this time the orchard referred to above used an amount sufficient to cover it 4.75 feet deep. The amount shown by the table would cover 9,383 acres to the same depth, but at least 2,000 acres of the lower land would not require so much water, so it is probable that, besides irrigating the present area properly considerable more land could be reclaimed if the water were stored and used economically. Again, if this water could be used when desired, fruit crops would take the place of the cheaper grain and alfalfa crops, and greater profit to the producer would result. Another feature to be considered is that the greater supply furnished in this way to the bench land would increase the return seepage which could be used on the lands below and decrease the supply needed from the stream. This extra supply could be transferred by purchase or, better, by the sovereignty of the State.

The small lakes at the head of the canyon already referred to have been segregated by the United States for reservoir sites and could easily be transformed into reservoirs. Besides these there are several small reservoir sites in the upper half of the canyon. From the facts presented it seems that the storage possibilities on this stream are good and should be considered.

There is another source from which water could be obtained to reclaim more land or to increase the water supply of Salt Lake City.

Between the head of the Hill Ditch and a point a short distance above the confluence of Big Cottonwood Creek with Jordan River measurements show that there is about 35 cubic feet per second return seepage entering the creek. This has been considered of little or no value except to furnish power, but recently $145,000 was asked for it. It has been used to furnish power to Miller Brothers' flour mills and for power and smelting purposes by the American Smelting and Refining Company. The former no longer use it, but still retain their right. The latter leased its right from the James Gordon estate, but it has expired recently. Water measurements were made at several places on the stream during the late summer and levels run to various points in the surrounding country with a view of learning how much appeared and where it could be used. The accompanying map shows the creek, the streams which are tributary to it, and the points to which reference will be made. Below the head of the Hill Ditch for a distance of three-fourths of a mile about 3 cubic feet per second returns to the channel of the creek. It is increased here by about 17.50 cubic feet per second, which rises on sections 9 and 16, T. 2 S., R. 1 E., Salt Lake base and meridian. Lower down another small stream, which late in the summer discharges about 2 cubic feet per second, runs into the Smelter Race or into the creek when not used for irrigation. It is known as Green River and its discharge fluctuates much more than the others. During the irrigation season most of this stream is diverted by the Brown Ditch (shown on the map, Pl. II) and is used on about 100 acres of low land which requires only a moderate amount of water, and produces pasturage, alfalfa, and grain.

There are several ways in which the water can be used beneficially, two of which will be discussed. The levels show that a portion of the water can be put into the Miller Branch of the Big Ditch high enough to irrigate most of its area and into the Big Ditch proper about 1 mile above its forks; also that a considerable area now irrigated by the Lower Canal could be supplied from this source as well as most of that irrigated by the Big Ditch. If the Big Cottonwood Consolidated Irrigation Company could buy this water and use it on the areas named, that now being used there could be used to reclaim new lands above. Salt Lake City, also, has recognized here an opportunity to get more water by purchasing the water and exchanging it for creek water which could be diverted near the mouth of the canyon and conveyed to its water mains. Of the two schemes suggested, the first could probably be effected more easily because there seems to be a feeling of distrust among the farmers toward the city on account of the position it took in the recent suit with the owners of Parleys Canyon Creek, and for this reason the proposed exchange would meet opposition. The one great obstacle to the immediate utilization of the water is the excessive price asked.

If the rights to the water of Big Cottonwood Creek could be equitably settled, the natural features of its drainage area, the topography of the tract susceptible to irrigation, and the fertility of its soil together with its proximity to a ready market are conditions which, if properly met, would result in one of the best and richest irrigated sections in the West.

The discharge of this stream is greater than that of any of those discussed and the other conditions are even more favorable to the generation of power. The Utah Light and Power Company takes some advantage of the opportunities and generates by the use of two plants about 2,400 horsepower of electrical energy. Several mines are being worked in the canyon and the owners of one of these expect to install a power plant. Besides these, several other claims have been made with this end in view.

SEEPAGE MEASUREMENTS.

The results of the seepage measurements made on Big Cottonwood Creek in September, 1902, are shown by the accompanying table. The points selected along the stream at which the measurements were made are designated as stations 1, 2, and 3. The measurement at Station 1 was made by the double 15-foot Cippoletti weir which was constructed and is maintained by the engineering department of Salt Lake City. It is situated at the mouth of the canyon just below the Utah Power and Light Company's generating plant. Station 2 is situated just above the head of the Green Ditch. It was selected with a view of obtaining an accurate measurement as well as to divide the creek into two sections essentially different in the natural conditions affecting seepage and evaporation. For the greater part of the distance, the creek in the upper section flows in the bottom of a wide gorge which it has cut through a delta deposited at the mouth of the canyon. The bed of the stream is composed of large, loose bowlders resting on very coarse gravel; the land on either side is covered with comparatively scanty vegetation, and as a result is hot and dry. These conditions cause excessive evaporation. The bed of the creek in the lower section is comparatively smooth, the land on either side is irrigated and covered with abundant vegetation. Station 3 was located at the head of the Big Ditch, the measurement being made over a 7½-foot Cippoletti weir.

The diversions were all measured over Cippoletti weirs of various lengths and the measurements were corrected for velocity of approach as were also the ones at Station 1. Complete seepage measurements were made on two occasions with the same general result, although as a result of the first trial the total loss was shown to be somewhat less than that given in the table and the loss, in the lower section, slightly greater.

Seepage measurements made on Big Cottonwood Creek, Salt Lake County, Utah, September, 1902.

FIRST SECTION.

Inflow: Creek at Station 1	cubic feet per second		32.54
Outflow:			
Brown & Sanford Ditch	cubic feet per second	2.34	
Upper Canal	do	4.47	
Tanner Ditch	do	5.82	
Creek at Station 2	do	12.55	
			25.18
Loss in section	cubic feet per second		7.36
Length of section	miles		2.5
Loss per mile	cubic feet per second		2.94
Percentage of loss	per cent		22.6

SECOND SECTION.

Inflow: Creek at Station 2	cubic feet per second		12.56
Outflow:			
Green Ditch	cubic feet per second	4.71	
Walker Ditch	do	.64	
Lower Canal	do	1.70	
Creek at Station 3	do	5.21	
			12.26
Loss in section	cubic feet per second		.30
Length of section	miles		2.5
Loss per mile	cubic feet per second		.12
Percentage of loss	per cent		2.4

Measurements were also made at the intake of the Utah Light and Power Company's flume and near the top of the pipe line leading to the power plant, with the following results: The discharge near the intake of the flume is 31.56 cubic feet per second, that near the top of the pipe line 31.23 cubic feet per second, showing a loss of 0.23 cubic feet per second in a distance of about 2 miles.

The Butler Ditch is taken from the creek between the place where the power company diverts the water into its flume and the power plant. Consequently the power company has to leave enough water in the channel of the creek to supply it. Although no measurements were made, it is apparent that the loss here is heavy.

LITTLE COTTONWOOD CREEK.

Like Big Cottonwood Creek, this stream rises in some small lakes at the head of its canyon whence it flows through the mountains in a comparatively straight course for a distance of about 10 miles. Although it is fed by numerous little streams, they are usually short lived, probably because the side canyons, although well protected, are short. The area drained by it is 27.72 square miles. The canyon is

narrow and deep and its sides from the mouth to the head are steep. The vegetation of the area is much the same in kind, distribution, and abundance as that on the Big Cottonwood area, although the hills are steeper and consequently not so well covered with soil. The usually heavy snow fall on the steep sides of the canyon near its head results in frequent snow slides. As was shown in the discussion of City Creek, these are favorable to an early run off. In spite of the facts that the area is provided with a fairly abundant growth of vegetation and that the main and the side canyons are well protected from the sun and retain some snow until late in the season, the area as a whole is not well adapted to act as a regulator of the water supply. Upon leaving the mountains, the stream takes a northwesterly direction, roughly paralleling Big Cottonwood Creek for a distance of about 11 miles, where it flows into the Jordan. For about one-half the distance the stream flows in a valley-like gorge similar to that in which Mill Creek flows, only much larger. The gorge varies in width from a quarter of a mile near the mouth of the canyon to about 1 mile near the settlement called Union. Its depth at the narrowest place is between 70 and 100 feet, but gradually decreases as the width increases until the gorge is finally lost in the plain below. In the lower portion of the gorge there are several little farms, the soil of which is very fertile.

This stream is also so situated that most of the irrigable lands on the east side of the valley could be irrigated from it provided the supply would permit. The location of the ditches which divert water from the creek and the lands irrigated from them is shown by the accompanying map (Pl. II). Of the land covered by the ditches, only a small part receives a good supply from Little Cottonwood. Part is irrigated from the east Jordan Canal which comes from Jordan River, but all irrigated by the ditches taken from the south side of the creek above Union, except what is under the Richards Ditch and a small area irrigated by the Sandy Ditch, receives early water only. That part above Union on both sides of the gorge is typical bench land and is especially adapted to the production of fruits. On the north side of the gorge the area to be reclaimed is considerable, though small in comparison with that which extends south from it. In and about Union the land is sandy and gravelly. The greater part of the remainder is a rich sandy loam, there being only small areas of the typical lowlands in the section. This tract on the whole is more fertile and, if well irrigated, would yield more abundantly than any described in this report.

From what has been said of the drainage area and the amount of land supplied with late water, it is evident that the flow of the stream fluctuates greatly. No measurements of consequence were made either on the creek or on any of its diverting ditches, there being no measur-

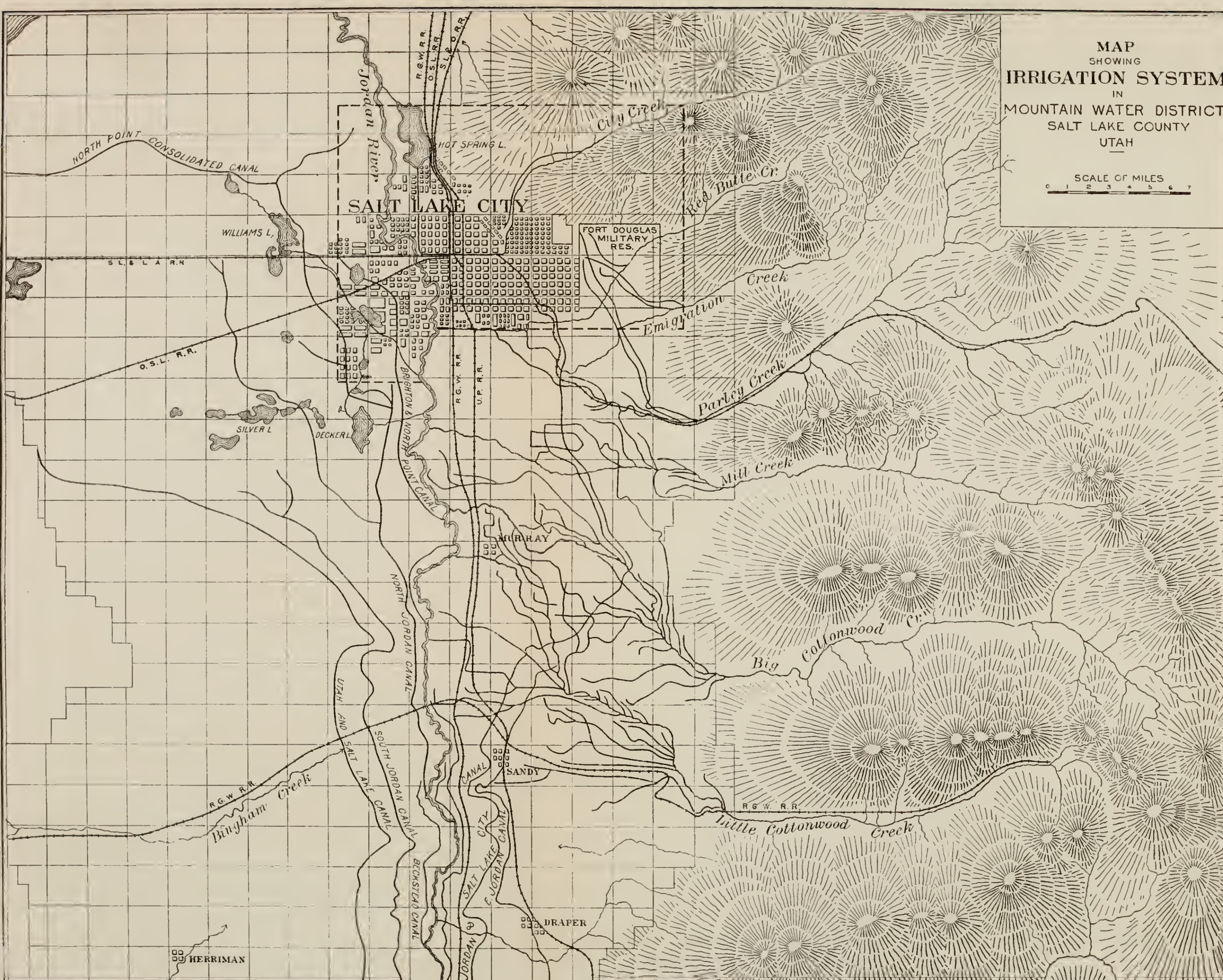
ing devices in use on which reliance could be placed. But an idea of the size of the stream at different times during the irrigating season can be gained from the results of current meter measurements made at the heads of the various diverting ditches. During the latter part of May the aggregate flow of all the ditches was found to be 205.96 cubic feet per second. About two weeks later, when all the ditches were filled and water was going to waste in the creek channel, another attempt was made to measure the flow of the different ditches, but the velocity of the water in some of them was greater than that for which the meter was rated and so the discharge had to be estimated. The flow at this time was about 400 cubic feet per second. Measurements made again in August show a total discharge of 13.8 cubic feet per second. During the winter months the stream is so low at times that difficulty is experienced in getting enough water for culinary purposes. It is somewhat later both in rising and in receding than is Big Cottonwood Creek. Not having complete measurements of Little Cottonwood Creek it is difficult to compare the discharges and areas of the Cottonwoods, but it is reasonably certain that the total run off per square mile is greater from the Little Cottonwood area than from that of Big Cottonwood, that the fluctuation of the former is very much greater, and that its area is less efficient as a natural reservoir.

The primary rights to the water of the stream are unsettled, but not especially complicated. The owners of the secondary or surplus rights are disputing among themselves over their respective rights as well as with the owners of the primary rights, and the lack of reliable data in both cases seems to stand in the way of peaceable settlement. Irrigation began on this stream in 1848, the land now irrigated by the Walker Ditch being the first to receive water from the creek. Soon after this date the Union and Jordan, the Cahoon & Maxfield, the Tanner, and the Richards ditches were constructed. As early as 1856 the late water of the stream was all appropriated and a scarcity was felt. In September of that year application was made by the appropriators to the county court, which at that time had power to grant rights and enforce a division according to the grants, to determine what portion of the stream each of the above ditches was entitled to. After examining the land and receiving all the evidence considered necessary, they decided that the areas now irrigated by the Richards and Walker ditches were each entitled to one-ninth of the stream; that those now irrigated by the Cahoon & Maxfield Ditch and the Union and Jordan Ditch were each entitled to five-eighteenths of it; and that the lands lying north of Union and now irrigated by the Tanner Ditch should receive two-ninths of it.

This decision has been since then the basis of division among the ditches named, but there are now other ditches which have recognized primary rights. These ditches are the De Spain Estate, South De

Spain, Sandy, Bissinger, Erickson, Greenwood, Brady, and Van Valkenberg ditches. No intelligent statement of either primary or surplus rights of any of these can be made, but the customs followed by them will be briefly stated. The South De Spain Ditch is essentially a surplus ditch, and its right as such is more nearly defined than that of any other ditch on the stream. Under a decree of court of Utah, dated May 7, 1896, it is entitled to a portion of the water from May 22 until July 22 of each year. While the stream is discharging over 185.31 cubic feet per second the ditch may divert all it will carry, but under that stage its supply is reduced in proportion to the fall of the stream. The capacity of the ditch was not determined when the decree was given, and it is alleged that it has been enlarged. After July 22 of each year the ditch claims a primary right to sufficient water to irrigate 15 acres of land. This claim has not been defined or agreed upon by those interested, but during the last season it received a constant flow of 0.5 cubic foot per second. The De Spain Estate Ditch diverts a portion of the surplus water onto the bench land on the north side of the gorge. After the surplus water is gone the owners of the ditch take what they think is necessary to irrigate about 20 acres of land. Its right is undefined, and much more is diverted than is used beneficially. The Sandy Ditch (Pl. III) is the largest of the ditches last named as owners of primary rights and among the largest and first appropriators of surplus water. As this ditch takes chiefly surplus water, the date on which construction work began, or of its appropriation, is important. This is not a matter of record, except in the company's book, which shows that work began in 1870. During the flood season its supply is increased and decreased as the creek rises and falls. After the flood season it is usually the aim to give it one-tenth of the stream at its various stages, although it is claimed by the principal owners of the primary rights that it is entitled to one-tenth of the stream only at its lowest stage. To make the allotment and regulate the flow of this ditch, the cross section of the stream above the point of diversion is measured in square inches, and the flow in the ditch is so regulated that its cross section is one-tenth of that of the stream. The Bissinger, Erickson, Greenwood, Brady, and Van Valkenberg ditches irrigate land in the bottom of the gorge. Their owners take what water they need any time they want it, and if a reasonable amount is diverted no objection is made. Little difficulty is experienced, compared with what would be expected from such an indefinite arrangement. The total area irrigated by the five ditches last named is about 125 acres.

After these smaller interests are satisfied the remainder of the stream is divided among the Richards, Tanner, Union and Jordan, Cahoon & Maxfield, and Walker ditches in accordance with the deci-


MAP
SHOWING
IRRIGATION SYSTEM
IN
MOUNTAIN WATER DISTRICT
SALT LAKE COUNTY
UTAH
SCALE OF MILES
0 1 2 3 4 5 6 7
SALT LAKE CITY
FORT DOUGLAS MILITARY RES.
Jordan River
HOT SPRING L.
WILLIAMS L.
SILVER L
DECKER L
NORTH POINT CONSOLIDATED CANAL
BRIGHTON & NORTH POINT CANAL
NORTH JORDAN CANAL
SOUTH JORDAN CANAL
UTAH AND SALT LAKE CANAL
BECKSTEAD CANAL
JORDAN & SALT LAKE CITY CANAL
E. JORDAN CANAL
City Creek
Red Butte Cr.
Emigration Creek
Parley Creek
Mill Creek
Big Cottonwood Cr.
Little Cottonwood Creek
Bingham Creek
R.G.W. R.R.
O.S.L. R.R.
U.P. R.R.
S.L. & L.A. R.R.
MURRAY
SANDY
DRAPER
HERRIMAN

MEASURING WEIR JUST ABOVE THE HEAD OF SANDY DITCH, LITTLE COTTONWOOD CREEK UTAH.

sion made in 1856. The supply of each ditch is regulated by a head gate and a measurement of its discharge is attempted over sills proportional in length to the amount to be diverted, it being assumed for convenience that each one-ninth of the creek is entitled to a 3-foot sill. Thus the Walker and Richards ditches, each being owners of one-ninth of the stream, receive their portions over 3-foot sills, while the Union and Jordan and the Cahoon & Maxfield, each owning 2.5 ninths or five-eighteenths of the stream, receive their amounts over 7.5-foot sills. No correction is made for the velocity of approach. Measurements made by the current meter in each ditch after an adjustment show that they do not accomplish the desired purpose, although satisfaction prevails among those interested. The total area irrigated by these ditches is about 6,400 acres, and the amount of water given to the primary owners by the decree already referred to, or the stage of the streams at which the surplus rights are recognized, is 185.31 cubic feet per second. The ditches having rights only to the surplus water, and the dates when construction work on each began, are given below: Atwood Ditch, 1867; Union and East Jordan Ditch, 1867; Stangrover Ditch, Nicol Ditch, Last Chance Ditch, 1892; Nickle Ditch, 1877; Lym Ditch, 1894; Thompson Ditch, 1888.

The Union and East Jordan and the Atwood ditches made their appropriations on the same day, but the former recorded its claim a few hours sooner, and so it is recognized as being the first appropriator of surplus water. It takes its supply through the Richards Ditch. Besides getting a portion of the surplus water, the Atwood Ditch is so situated that it gets all the return seepage during the summer between the place where it is diverted and the head of the Walker Ditch. The water is turned from the channel of the creek into Green River and diverted into the ditch lower down. (See map, Pl. II.) The ditch irrigates about 650 acres of land. On account of the leniency of the primary owners the ditches depending on surplus water take water from the stream before it has reached the surplus stage in the order of the dates of their appropriations. In fact, as long as their needs are reasonably respected the owners of primary rights make no objection. In case, however, it becomes necessary to restrict the use of the surplus water the latest ditches have their streams reduced first. From what has been stated, it is clear that a just settlement of the rights would be somewhat hindered by a lack of sufficient data. To illustrate the meagerness of the information regarding the flow of the stream and the capacities of the ditches, and consequently their rights, one of the ditch companies is now before the court asking for more than twice the present capacity of its ditch and about one and one-half times what is usually in the creek in the latter part of the period for which it is asked.

Several opportunities for improvement present themselves. One of

the least expensive and probably most effective in proportion to the outlay is the installation of measuring devices. The kind of measuring device to be used depends among other things upon the supply which the different ditches receive. All the ditches taking surplus water should have rating flumes and those diverting both primary and surplus water, with the exception of the smaller primary ditches which could measure their supply at all times by means of Cippoletti weirs, should have rating flumes and Cippoletti weirs combined. The rating flumes could be used to measure the flood water, after which a bulkhead provided with a weir plate near the top could be dropped in front of or into the flume to measure the later and more valuable water. The data collected from these measuring devices would be of great value in establishing the relative rights of the ditches and in a just division of the water. This would also be a means of determining the storage possibilities and the loss by seepage and evaporation. Although there is a great fluctuation in the discharge of the stream and at times it becomes very high, nearly all of it is diverted for irrigation. Notwithstanding the fact that there are a number of good reservoir sites in the canyon, including the lakes at its head, and that the late water is far more valuable than the early, most of the surplus water is claimed by people not interested in the primary water, and so the problem of storage presents more difficulties on this stream than on Big Cottonwood Creek, where the primary ditches also own the right to most of the surplus water. But the owners of the primary rights divert large volumes of the early flow to produce either alfalfa or grain. This could be stored and used later on fruit crops in diminished quantities with greater profit to the owners. If enough were known of the rights of or volumes diverted by the ditches depending on surplus water at different stages of the creek, it is feasible and would be profitable for these ditches, also, to store their share and use it later.

No seepage measurements were made on this stream during the year; but several years ago a prominent engineer of Salt Lake City determined that there was about 16 per cent of the flow lost in this way between the mouth of the canyon and Union. This loss could be reduced by keeping the creek channel in a better condition. The loss by seepage in the different ditches is considerable and worth investigating. Although lack of data prevents an intelligent discussion of the possibilities of the stream, it is safe to say that the present profits could be doubled if the total run-off were used to the best possible advantage.

Conditions on this stream during the greater part of the year favor its use for generating power, but the fluctuation is so great that only small plants could be operated continuously. However, a number of claims have been made for this purpose.

STREAMS SUPPLYING DRAPER AND CRESCENT.

South of Little Cottonwood Creek for a distance of about 4 miles, the face of the mountain is exceptionally steep and high. Its lower part is covered principally with scrub oak and sagebrush, but higher these are replaced by pine and quaking asp. The precipitation of past ages, aided by other agencies, has eroded small canyons which extend toward the east from the bottom to the top of this precipitous area. As would be expected, these canyons are very steep and rugged, and their numerous coves and ravines afford good lodging places for the wind-driven snow. The streams issuing from the canyons named in the order of their occurrence from the north toward the south are: North Dry, Middle Dry, South Dry, Rocky Mouth, and Big Willow creeks. Of these streams North Dry Creek is the largest and most important. From the base of the mountain its canyon extends eastward around the north end and toward the top of the area, where it turns and extends southward. The stream finds its source in a small lake which lies in a solid granite formation, back of the high front peaks, at an elevation of nearly 11,000 feet. The other streams find their rise in, and are supplied entirely from the area described. The area is but poorly provided with soil, and especially so near the top and, therefore, after the greater part of the snow is melted the water supply is small. However, the snow remains fairly late; in fact, it is perpetual on limited areas. High water usually begins in May or the first part of June and continues five or six weeks, depending on the snow fall. No measurements were made, but the variation of the discharge of each is probably greater than that of Little Cottonwood Creek. All the water of Big Willow, Rocky Mouth, South Dry, and Middle Dry creeks and one-half of the flow of North Dry Creek is owned and controlled by the Draper Irrigation Company. This supply is collected at the base of the mountains by means of a canal and taken to a little town called Draper in the extreme southeastern part of the area under discussion. These streams supply the town with culinary water and irrigate something over 1,000 acres of land. This land is admirably adapted to fruit growing and large quantities of fruit are produced. The water supply is divided among 7 ditches; the rights of each are definitely settled, and the quantity of water given to each is in proportion to the number of acres of land under it. The division is made by means of head gates whose sills are proportional in length to the respective amounts diverted, and it is aimed to bring the water to a standstill at the place of diversion. This, and the Crescent system probably approach accuracy in division more nearly than any of the systems discussed except that of Big Cottonwood Creek. The company is incorporated and has a capital stock of $30,300. It is

progressive, its resources being used to good advantage. There is a demand in Draper for an earlier and a later supply than the streams furnish. In order to supply the demand, the Draper and Crescent Irrigation companies are constructing a reservoir for which the lake at the head of North Dry Creek Canyon is being used as the site. The area of the lake is about 18 acres and it is aimed to raise its level about 36 feet. By so doing about 800 acre-feet could be stored. Mention of the altitude and the formation in which the lake is situated has already been made. The dam is being constructed of masonry. All but the cementing material is at hand but, on account of its almost inaccessible location, great difficulty is experienced in conveying this to the dam, as it has to be carried on horses for about five miles of the distance. Most of the labor is furnished by those interested and only about two months of the year is spent in construction work, consequently the progress is slow. The dam is partly constructed, and 16 feet of water over the area of the lake was stored during the flood season of 1902. On account of the altitude, other things not considered, the evaporation would be excessive, but the numerous springs which rise in the lake probably more than make good the loss by seepage and evaporation. Although the area drained into the lake is small, the snow fall is usually very heavy, and no difficulty will be experienced in obtaining enough water to fill it once. It is thought by some that it can be filled during the winter and emptied in the early spring to irrigate early fruit and vegetables and then filled again during the high-water season to be used in the late summer.

The division of North Dry Creek between Draper and Crescent Ward is accomplished by running the water into a flume having a splitter in the middle of it which is intended to divide the stream into two equal parts. Crescent is what has been referred to as a bishop's ward, and is situated about 5 miles west of the mouth of North Dry Creek Canyon. One-seventh of its supply is diverted near the mouth of the canyon by the Granite Ditch. During the flood season the remainder of the stream flows in the bottom of a gorge toward Crescent, and is diverted a short distance above that place by the Big and Mickleson surplus ditches. Later in the season, when the supply is small, it is transferred to an open rock-lined conduit, which was constructed on the bench south of the gorge for the purpose of saving the great loss sustained by seepage and evaporation when the stream is allowed to flow in the channel of the creek. The conduit cost about $2,000 per mile, and those interested are satisfied with their investment. The greater part of the supply comes early in the season, and the principal crops grown are alfalfa and grain. The stored supply is used for fruit crops and culinary use. The community is also doing its utmost to use the water to the best advantage.

BUTTERFIELD CANYON CREEK.

Butterfield Canyon Creek finds its source in the Oquirrh Range of mountains about 30 miles southwest of Salt Lake City. The creek has three branches, two of which rise in the summits of the range and flow in an easterly direction. The third rises near the top of a spur which extends eastward from the main range. This branch flows in a northeasterly direction toward the mouth of the canyon and joins on its way the upper branch of the two flowing eastward. At the mouth of the canyon, or more properly the canyons, the third branch enters the main stream, which originally flowed in a northeasterly direction toward the Jordan. The canyons are shallow and the walls are steep and but poorly protected with vegetation, although the growth of sagebrush and scrub oak is plentiful and there are some maple and birch on the bottoms of the canyons and in protected places on their sides. There are also a few pines near the heads of the canyons. The snow fall on these mountains, owing to their altitude and the character of the vegetation, is very much lighter than that on the Wasatch Mountains, and consequently the run off from the drainage areas is correspondingly smaller. No measurements of the stream were made, but the fluctuation of its discharge is great. The normal flow of the stream is barely sufficient to furnish a little town called Herriman with enough water for culinary purposes and to irrigate small gardens and orchards. The flood water is diverted and produces principally alfalfa and grain. The rights present nothing of unusual interest, and as the stream is comparatively unimportant a discussion of them will be omitted.

BINGHAM CANYON CREEK.

This stream rises about 3 miles north of the head of Butterfield Creek and flows through the mountains in a northeasterly direction for about 5 miles. From the mouth of the canyon it flows in an easterly direction toward the Jordan. The canyon, with respect to its topography and vegetation, is much the same as Butterfield Canyon. Very little of the water is used for irrigation, there being only a few fields of alfalfa and grain near the mouth of the canyon. The stream is owned and controlled by Bingham, one of Utah's prosperous mining camps. Besides furnishing culinary water for the town the stream is used to some extent in the concentration of ores.

SUMMARY.

The discussion of each stream has included a description of the topographic features of its drainage area, a statement of the relative area of soil, the kind of vegetation and its distribution, the run off, and the efficiency of the area as a natural reservoir with the probable

conditions influencing them. The location and a general description of the irrigable lands and, on some streams, the relative value of irrigated and nonirrigated lands have been given, together with something of their productiveness when properly irrigated. A statement of the existing conditions regarding the water rights has been presented, and the principal causes which have governed their development have been given. Attention has been called to commendable features in the management of drainage areas and irrigation systems. The results of seepage measurements on Big Cottonwood and Mill creeks have been given, and feasible schemes for saving this water, improving irrigation systems, and storing flood water of different streams have been suggested.

An inspection of the Salt Lake County records shows that the following conditions exist: That only a very small percentage of the recognized water rights has been recorded; that most of those recorded are of comparatively little importance, as they refer to small streams and springs; that the responsibility for the failure of the majority of irrigators to have their rights recorded does not rest entirely with them, as the law states plainly that such failure shall not result in a forfeiture of right; that the records are indefinite and there is no means of determining from them alone the validity of any recorded claim.

From the available records and evidences it seems that the attempts of the Mormon Church authorities or their ecclesiastical courts to settle rights in this district have met with little success, but their influence in avoiding legal difficulties has been marked. Their policy seems to have been "live and let live." This has probably resulted in a greater complication of rights, because their attempted settlements, their influence in allaying strife, and their brotherly feeling have postponed definite settlement. But even though this is true, the ultimate effect will be good. Through their policy greater areas have been partially irrigated, and when a final settlement is effected and the rights are definitely known, study and investigation will result and the limited water supply will be used to the greatest advantage; whereas, if the rights had been settled earlier and abundant supplies given to the first appropriators, smaller areas undoubtedly would have been reclaimed.

ACKNOWLEDGMENTS.

Acknowledgment is hereby made to Mr. L. C. Kelsey, city engineer, and Mr. I. M. Fisher, land and water commissioner of Salt Lake City, for data relative to City, Emigration, and Parleys Canyon creeks; also to the officers of canal and ditch companies interested in Parleys Canyon, Mill, and Big and Little Cottonwood creeks, and the streams furnishing the water supply of Draper and Crescent for information and assistance.

THE USE OF WATER FROM THE WOOD RIVERS, IDAHO.

By Jay D. Stannard,
Assistant in Irrigation Investigations.

Irrigation investigations in the Wood River valleys disclosed a great variety of conditions. The Big Wood River not only has its flood water and low-water periods, but there are months during each year when the channel in the lower section of the river is entirely dry except for pools of stagnant water. Above its junction with Silver Creek the Little Wood River is subject to the same variations as is the Big Wood, since its supply is largely derived from the melting snows. Below its junction with Silver Creek the supply is drawn almost entirely from that stream, whose source is in large springs situated in a comparatively level country. The fluctuation in the flow of these springs is not great, the flow being slightly greater in the fall and winter than it is in the spring and summer. The influence of this stream on the lower Little Wood is, therefore, to make its flow more constant.

Both Big and Little Wood rivers in their upper courses flow through comparatively large valleys of fine land, much of which is still unreclaimed, while the middle courses of both are through broken lava, where land suitable to cultivation is very limited.

Much of the land in the upper valley of the Little Wood is irrigated by means of community ditches. One party in the upper valley of the Big Wood rents and distributes water to others who have no share in the ownership of the canal. Most of the ditches from Big Wood, Silver Creek, and Little Wood River below Silver Creek are the property of the owners of the land irrigated. The waters of Little Wood River and its tributaries are nominally distributed under the decree of the courts by a water master appointed by the court. The waters of Big Wood River, with the exception of a few of the smaller tributaries, are not controlled by any system of distribution; each irrigator may go to the stream and take what water he chooses if the natural conditions will permit.

For these reasons it is doubtful if there exists in the State another area containing such a number of different conditions, or one more nearly typical of the conditions prevailing throughout the State.

BIG WOOD RIVER.

Big Wood River has its source in the southern slope of the Boulder Mountains, in the south-central portion of Idaho (map, Pl. IV). The Boulder Range is a spur from the Sawtooth Range, and extends southeasterly from it. Salmon River, East Fork of Salmon River, and Big Lost River drain the northern slope of the Boulder Range. The general course of Big Wood River for a distance of about 20 miles is to the southeast, where it receives the waters of the North Fork. In this portion a number of small tributaries enter from both sides. Baker Creek, from the south, and the two Boulder creeks, from the north, are the most important. At the mouth of the North Fork the direction of the river changes to more nearly south, passing the towns of Ketchum, Hailey, and Bellevue. In this distance of about 25 miles the river makes about 8 miles to the east. Ketchum is the terminus of the Wood River branch of the Oregon Short Line Railroad, and is located about 7 miles below the mouth of the North Fork. Near this point Trail Creek, from the east, and Warm Springs Creek, from the west, join the river. These are the most important tributaries of the upper river. Hailey, some 12 or 14 miles below Ketchum, is the county seat of Blaine County. Bellevue is 5 miles below Hailey. Between Ketchum and Bellevue, on either side of the river, are a number of small streams. Those on the east, beginning with the highest, are: East Fork, Indian Creek, Quigley Creek, and Seamands Creek; those on the west are Greenhorn, Deer, and Croy creeks. The ordinary flow of these streams, with the single exception of East Fork, does not reach the river; they all, however, furnish water for the irrigation of lands adjacent to them. At Bellevue the river takes a course nearly due south for about 3 miles, where it turns slightly to the west for about 7 miles, then again changes direction and flows about 4 miles due west to meet the waters of Camas Creek.[a] Near the point where the direction changes to the west, the river receives the waters of Spring Creek from the east, and for a few miles above this point the flow of the river is increased by a number of springs that rise in or near the channel. About a mile above the point where Camas Creek joins the Big Wood, Rock Creek flows in from the north. The ordinary flow of this stream where it enters the river is very small, the water having been taken out above for the irrigation of lands along the creek.

Camas Creek, the largest tributary of Big Wood River, flows through and drains Big Camas Prairie. Its length is about 50 miles and its

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[a] The local name of this stream is Malade River, but as the stream formed by the junction of the Big and Little Wood rivers bears this name, the tributary, to avoid confusion, will be called, in this paper, Camas Creek, the name given on the map of the land office of Idaho.


MAP
OF
BIG AND LITTLE WOOD RIVERS
IDAHO
SCALE OF MILES
0
5
10
15
LEGEND.
IRRIGABLE LAND
POINTS OF STREAM - MEASUREMENTS
N. Fork
Proposed Res.
Trail Creek
KETCHUM
GIMLET
HAILEY
BELLEVUE
E. Fork
Proposed Res.
Soldier Creek
Willow Creek
Camas Creek
Proposed Res.
PICABO
CAREY
River
COTTONWOOD DITCH
Proposed Res.
Wood
WOOD RIVER BRANCH O.S.L. R.R.
Wood
Big
Little
Wood
GOODING
SHOSHONE
OREGON SHORT LINE R. R.
SNAKE R.
Malade River

course is almost due east. The hills lying to the south of Camas Creek are low, and it receives no tributaries of importance from that direction. A number of tributaries flow into it from the mountains on the north. Of these, Soldier and Willow creeks are the largest.

After uniting with Camas Creek the Big Wood turns abruptly to the south, and its course for the next 30 miles is a little east of south. It again makes an abrupt bend to the west, continues this direction about 15 miles, and then turns to the southwest. Fifteen miles lower down it joins the Little Wood River, and together they form the Malade, the course of which is due south for about 15 miles, then due west for about 6 miles, to the Snake. In a distance of 4 miles below Camas Creek the river receives the waters of four streams that are fed by springs rising in the bottoms not far from the river. Notwithstanding these additions, which, as shown later in this report, amount to from 7 to 15 per cent of the flow of the stream, there occurs a heavy loss in this section amounting to from 26 to 30 per cent. About 4 miles below Camas Creek the river enters a canyon, cut through a low range of lava hills, through which it flows for a distance of 4 or 6 miles. Portions of the channel lie on the surface of the lava bed, while in other places it lies in a crack in the lava, 20 to 50 feet below the surface. At the surface this creek is so narrow in places as to permit one to step from one side to the other. For nearly 7 miles above their junction Big and Little Wood rivers are nearly parallel and but little more than half a mile apart, and above this point for nearly 17 miles they are not more than 3 miles apart.

The Boulder Mountains are about 7,000 feet high, and the abundant snow fall furnishes a supply of water that, up to about the middle or the last of June, is more than sufficient for all demands of irrigation for the area at present under cultivation. In common with all Western streams, the Big Wood is subject to heavy floods in spring and early summer. The portion of the stream below Camas Creek has two flood periods. The earlier is due to water coming down Camas Creek from Big Camas Prairie and the low hills lying to the north, whose elevation does not exceed 5,000 feet, and is several weeks in advance of the main flood which comes from the higher Boulder Range. After the flood season has passed, the flow of the river falls very rapidly. So sudden is this decline that only a few days pass before the quantity of water is not sufficient to reach the lower end of the river. After this stage, along the lower course of the river, water is found only in stagnant pools, and to find running water one must go up the stream farther and farther each day. The snowfall during the seasons of 1900, 1901, and 1902 was much less than the normal, and in consequence the water in 1902 in Big Wood River was lower than ever before known. On August 20, 1902, at a point about 40 miles above the junction of the Big and Little Wood rivers, the water had ceased flowing.

The irrigated lands on the Big Wood begin at Ketchum, and between that town and Bellevue are located almost entirely on the left bank of the river. The valley along this section varies in width from a half mile to a mile. The principal ditches that serve the land through this portion of the valley are taken from the river below the mouth of East Fork. The names of the ditches, given in the order in which they are taken from the river, are: Miser, Thompson, Riley or the Big Ditch, Osborn, Osborn & Webber, Purdum, Wingate & Angel, Miller & Packard, Whitton, Campbell, Peterline, Adams, Arthur Brown, Grover-Flower, Jones, and Sharpe. Of these the Campbell, Peterline, Grover-Flower, Jones, and Sharpe ditches are taken from the right bank of the river, the remaining ones from the left bank.

Below Bellevue the valley widens out, forming a valley somewhat triangular in outline, with sides some 12 to 14 miles in length. Bellevue is located at the northern angle of this triangle. The river flows through this valley in a southwesterly direction. Near the base of the triangle and west of the river is a large body of new land, containing some 8,000 acres, under process of development. The Grover-Flower, Jones, and Sharpe ditches supply water to portions of this land. On the southeast the valley joins a level country that is drained by Silver Creek, a tributary of Little Wood River. The divide between the two valleys is so low and indistinct as to be practically imperceptible. A portion of the land in this section is served with water through the Miller & Packard and the Arthur Brown ditches. Part of the area watered by these ditches lies within the watershed of Silver Creek, so that stream has the benefit of the waste water and seepage from these lands, to the disadvantage of Big Wood River and the lands located below on that stream.

Below the mouth of Camas Creek are two ranches served with water from Big Wood through the Rice and Calhoun ditches. Below this point the area of irrigated land is limited, and the farms are small, irregular, and broken by the outcropping of lava. The fields are usually adjacent to the river and are served by small ditches built by the individual farmers.

At the Cottonwood ranch, which is located some 14 or 16 miles below Camas Creek, the Big Cottonwood Canal is taken out on the left bank of Big Wood River. It consists partly of an artificial channel and partly of an old water course and is used to convey water to Little Wood River for the use and benefit of the ranches on the lower portion of that stream. It enters the Little Wood River about 12 miles above Shoshone. It is regarded as a high-water ditch and thus far has been used only to take advantage of the flood waters of the Big Wood River, and its head gate has usually been shut down upon the request of the irrigators of the lower sections of Big Wood River. The Cottonwood ranch is served through this canal. Below this point

the ranches are isolated. The ditches are small and are given the names of the owners. They occur in the following order: Kinsey, Thomason, Canzler, Gherig, Gwin-Wallace, Wrastler, Darrah, Gherig, Butler, Peck-Dudley, Fred Gooding, Sims, Gomez, Campbell, Silva, Haydon, Savage, Poor Man's, Silk, Schooler, Bliss-Raymond, Jones, Warden-Vandergraff, Burnett, Mullins, Frost, Mullins, and Clifford.

LITTLE WOOD RIVER.

The source of Little Wood River is on the southern slope of the Boulder Range some 40 or 50 miles southeast of the source of Big Wood River. Its general course for the upper 45 miles is nearly due south. About 5 miles above where its channel receives the discharge from Silver Creek it turns to the southwest. This general direction is maintained as far as Shoshone, 38 miles below. It then makes a bend to the west, and continues in a westerly course for a distance of about 25 miles until it unites with the Big Wood to form the Malade.

Silver Creek is the only tributary of Little Wood River that will be considered. Its length is about 25 miles. It has its source in a number of large springs rising in an adjoining valley which may almost be considered a portion of the valley of the Big Wood River, some 12 to 14 miles southeast of Bellevue. A question arises as to which should be called a tributary—Silver Creek or the Little Wood—as, during a greater part of the irrigating season, the larger quantity of water comes from Silver Creek.

The settlement of Carey is located on Little Wood River 6 or 8 miles above its junction with Silver Creek. It is situated in a valley of several thousand acres. The portion of the valley under cultivation is served by two community ditches which head some 5 or 6 miles above Carey, within about three-fourths of a mile of each other. The upper is known as the West Side Ditch, the lower as the East Side Ditch. During the ordinary irrigation season these ditches, although they divert the entire flow of the river, furnish but a scanty supply for the area under cultivation.

Much of the land in the upper valley of Silver Creek (Pl. V) is springy and marshy and subirrigates from the water rising in it. Because of the nature of the source of this stream it is not subject to floods. Its flow is quite constant, and the fluctuations to which it is subject are reversed in point of time in comparison with other Western streams, the highest water coming in the fall and the low-water period occurring in the spring. The increased flow usually begins in August.

Below the junction of Little Wood River and Silver Creek the course of the stream is through lava beds, but it differs from the Big Wood River in that its channel is on the surface and not in fissures or canyons.

The cultivated lands on Silver Creek and Little Wood River are located mainly at the extreme ends of the valley. The lands in the upper valley are in a compact body in and through which flow the various streams that unite to form Silver Creek. A little below Picabo the lava outcrops and from this point the ranches are not always contiguous but are found irregularly along the stream, sometimes miles apart, as patches of soil may be found amid the ever present lava rock. Along the lower part of the course of the Little Wood larger areas susceptible of irrigation are found.

The lands between Picabo and the lower end of the Little Wood Valley are served by ditches taken from the stream in the order in which they are arranged in the following list: Neidermeyer & Loving, Brett, Lawson, McGlochlin, Kelley, Adams, Anthony, Adams, Shanahan, Hodgman, Gooding, Burns, McNulty, McNulty & Morley, Kelly, Sawyer, Hughes, Baugh & Anderson, Baugh, Bock, Wheeler, White, Dill, Shoshone Town, Mabbit, Millsap, Murphy, Stiffler, McFall, Hunter, Johnson, Fred Gooding, Kelley, Jones, Fred Gooding, Silva, Fred Gooding, Woodworth, Frank Gooding, Woodworth, and Dwyer.

RESERVOIR SITES.

The maximum discharge of most of the streams of Idaho occurs in May and June, during which period the flow of the streams is usually greater than can be utilized for irrigation. At these times all claims to water can be satisfied, and water in large quantities is flowing past the lowest ditches on the stream. Later in the season the snows at the sources of the streams have all melted and the supply of water is diminished. The flow of the streams sometimes decreases very suddenly and many who would like water for irrigation find that no water is available for them, and their crops suffer. While visiting the valley of the Wood rivers the attention of the writer was called to some places that with more extended investigations may prove to be valuable sites for storage reservoirs.

About three-fourths of a mile above the junction of Camas Creek with Big Wood River the creek passes through a gap in the rock. The walls are nearly vertical for about 65 feet, and are a little less than 400 feet apart at the top. Just above this gap the valley widens out, forming a basin of irregular outline containing 100 or 120 acres. Through this valley the fall is so slight that in low water the creek becomes a sluggish slough with a scarcely perceptible current. Above this valley the canyon has a width across the top of 1,000 to 1,200 feet for a distance of some 4 miles. The fall in this portion of the creek is very slight. It was estimated that a dam 60 feet in height would back the water up for a distance of 4 or 5 miles. The capacity of the reservoir with a dam 60 feet in height was roughly estimated at 10,000

SILVER CREEK VALLEY, IDAHO, LOOKING ACROSS THE VALLEY FROM NORTH TO SOUTH.

to 12,000 acre-feet. The writer has no data for estimating the discharge of Camas Creek during the flood period, but from the statements of those who are familiar with this stream there is little doubt that the supply is ample to fill a reservoir of this capacity each season with the water that usually is allowed to waste into the channel of Snake River through the Big Wood. A reservoir of this capacity located here would relieve the situation throughout the entire valley of the Big and Little Wood rivers except that portion of the Little Wood Valley situated above the junction of Little Wood River and Silver Creek, since it is estimated that there are not more than 2,000 acres at present irrigated from the Big Wood River below this reservoir site, so that a portion of the water that might be stored here could be carried through the Cottonwood Canal and used for the irrigation of lands along the lower Little Wood. This would permit a greater diversion of water from Silver Creek and from Little Wood above the point where the Cottonwood Ditch discharges its waters into Little Wood River. Measurements of the flow of the river show very large losses below this site, and it is possible that this would make storage here impracticable (see pp. 78–81).

A possible site is located in the channel of Little Wood River some 12 miles above Carey. The width of the valley increases at this place to about half a mile and its length is about 4 miles. It is estimated that by means of a dam 30 feet in height an approximate area of 1,000 acres could be covered to a depth of 15 feet. This would give an approximate capacity of 15,000 acre-feet. The valley at the point where the dam would be located is between 1,500 and 1,800 feet in width, at a height of about 70 feet. This water could be utilized on lands in the valley of the upper Little Wood, insuring crops on the lands that are now cultivated and permitting the reclamation of new land.

Through the courtesy of Mr. F. C. Mandell, C. E., of Hailey, the writer was given the following data of a reservoir site located in the channel of Big Wood River, some 23 miles above Hailey, and just below the mouth of Boulder Creek. The length of a dam 60 feet in height would be 500 feet at the top, 350 feet at the bottom. The area covered by water at the 60-foot contour would be 231 acres and the capacity of the reservoir at this contour would be 5,875 acre-feet. Water stored here could be used along the upper course of the river.

A company organized among the irrigators of the lower Big Wood Valley has for its object the construction of two reservoirs which are to be located 10 or 12 miles north of Shoshone, near Hanley Butte. The capacity of these reservoirs, as estimated by the company's engineer, Mr. J. W. Waldron, of Shoshone, will be about 3,000 acre-feet. The height of the dams required to impound this water will be about 10 and 19 feet, respectively. The reservoirs are to be filled by means

of a ditch from the Big Wood. This ditch will be about 15 miles long and will have a capacity of 60 cubic feet per second. The estimated cost of the dams and ditch is about $10,000.

SEEPAGE MEASUREMENTS.

BIG WOOD RIVER.

Through the courtesy of Mr. H. H. Kinsey, of Shoshone, the writer was enabled to make a series of seepage measurements to determine the loss or gain on Big Wood River. These measurements were made on July 11, 12, and 13, 1902. They were commenced at the mouth of Camas Creek and were carried down the river some 35 miles to a point nearly opposite Shoshone. These measurements are given in the following table:

Seepage measurements Big Wood River, July 11, 12, and 13, 1902.

[In cubic feet per second.]

FIRST SECTION.

Inflow:		
River below mouth of Camas Creek	132.93	
Tributaries in section	9.46	
		142.39
Outflow:		
Diversions in section	4.21	
River below Reed Creek	101.54	
		105.75
Loss in section		36.64
Length of section ... miles		4.00
Loss per mile		9.16
Percentage of loss ... per cent		26.00

SECOND SECTION.

Inflow: River below Reed Creek		101.54
Outflow:		
Diversions in section	7.68	
River 16 miles below Camas Creek	86.43	
		94.11
Loss in section		7.43
Length of section ... miles		12.00
Loss per mile		.62
Percentage of loss ... per cent		7.00

THIRD SECTION.

Inflow: River 16 miles below Camas Creek		86.43
Outflow:		
Diversions in section	3.25	
River 20 miles below Camas Creek	61.40	
		64.65
Loss in section		21.78
Length of section ... miles		4.00
Loss per mile		5.45
Percentage of loss ... per cent		25.00

FOURTH SECTION.

Inflow: River 20 miles below Camas Creek		61.40
Outflow:		
Diversions in section	3.14	
River at Gwins, 35 miles below Camas Creek	44.13	
		47.27
Loss in section		14.13
Length of section ...miles		15.00
Loss per mile		.94
Percentage of loss ...per cent		23.00

TOTAL SERIES.

Inflow:		
River below mouth of Camas Creek	132.93	
Tributaries	9.46	
		142.39
Outflow:		
Diversions	18.28	
River at Gwins	44.13	
		62.41
Loss in section		79.98
Length of section ...miles		35.00
Loss per mile		2.29
Percentage of loss ...per cent		56.00

Such heavy losses were shown in certain sections of the stream that it was decided to repeat the measurements, if possible, later in the season. This was made possible through the aid of Mr. Lewis Walter, of Gooding, who furnished a team and camping outfit and accompanied the writer on the trip. These measurements, occupying five days, were commenced on August 16, 1902, at Gimlet, a point on the river about 7 miles above Hailey, and were continued down the river for a distance of about 52 miles. Here the channel of the river became dry, except for the stagnant pools found in the deeper parts of the channel along the lower section. The results of these measurements are given below.

Seepage measurements, Big Wood River, Idaho, August 16, 1902.

[In cubic feet per second.]

FIRST SECTION.

Inflow:		
River at Gimlet	146.41	
Tributaries in section	1.71	
		148.12
Outflow:		
Diversions in section	181.29	
River below Star Bridge	64.71	
		246.00
Gain in section		97.88
Length of section ...miles		9.50
Gain per mile		10.30
Percentage of gain ...per cent		66.00

SECOND SECTION.

Inflow: River at Star Bridge		64.71
Outflow:		
Diversions in section	58.74	
River 17 miles below Gimlet	Dry.	
		58.74
Loss in section		5.97
Length of section ... miles..		7.50
Loss per mile		.80
Percentage of loss ... per cent..		9.00

THIRD SECTION.

Inflow: River 17 miles below Gimlet	Dry.
Outflow: River 28 miles below Gimlet	42.01
Gain in section	42.01
Length of section ... miles..	11.00
Gain per mile	3.82

FOURTH SECTION.

Inflow:		
River 500 feet above Camas Creek	42.01	
Camas Creek	10.73	
		52.74
Outflow: River 300 feet below Camas Creek		52.74

FIFTH SECTION.

Inflow:		
River 300 feet below Camas Creek	52.74	
Tributaries in section	7.75	
		60.49
Outflow:		
Diversions in section	1.70	
River 400 feet above Reed Creek	40.47	
		42.17
Loss in section		18.32
Length of section ... miles..		3.75
Loss per mile		4.88
Percentage of loss ... per cent..		30.00

SIXTH SECTION.

Inflow:		
River 400 feet above Reed Creek	40.47	
Reed Creek	.04	
		40.51
Outflow:		
Diversions in section	7.18	
River at Cottonwoods	19.43	
		26.61
Loss in section		13.90
Length of section ... miles..		13.00
Loss per mile		1.07
Percentage of loss ... per cent..		34.00

SEVENTH SECTION.

Inflow: River at Cottonwoods		19.43
Outflow:		
Diversions in section	5.14	
River at Thomasons Ford	4.86	
		10.00
Loss in section		9.43
Length of section ... miles		3.00
Loss per mile		3.14
Percentage of loss ... per cent		49.00

EIGHTH SECTION.

Inflow: River at Thomasons Ford	4.86
Outflow: River above Gherig Ditch	Dry.
Loss in section	4.86
Length of section ... miles	4.00
Loss per mile	1.22

TOTAL STREAM.

Inflow:		
River at Gimlet	146.41	
Tributaries	20.23	
		166.64
Outflow:		
Diversions	254.05	
River above Gherig Ditch	Dry.	
		254.05
Gain		87.41
Length of section ... miles		52.00
Gain per mile		1.68
Percentage of gain ... per cent		52.00

From these measurements it will be seen that, notwithstanding the fact that large quantities of water are diverted from the river in the upper section, large quantities are being returned to it as seepage. The valley in this section is quite narrow, not much exceeding a mile in width. The slope is quite heavy toward the river, the soil is of a gravelly nature, and the water applied to the ranches here soon finds its way back to the stream. The gain in this section is a little more than 10 cubic feet per second per mile. Of the ten ditches that head in this section nine supply water to lands in the valley adjacent to the river. One, the Miller & Packard Ditch, supplies water to lands beyond the low divide between Big Wood River and Silver Creek, and the seepage from lands watered by the ditch is not returned to the Big Wood River, but goes to augment the flow of Silver Creek and the Little Wood. In the second section, which extends between 9½ and 17 miles from the upper points of measurement, a loss is shown amounting to a little more than three-fourths of a cubic foot per second per mile. At

the end of this section the channel of the river is dry. Between the seventeenth and twenty-eighth miles the river gains 42 cubic feet per second, or nearly 4 cubic feet per second per mile. Camas Creek comes into the Big Wood at this point and increases the flow by 10.73 cubic feet per second. In the next section, which is taken from 28.25 miles to 32 miles below Gimlet, the river sustains a heavy loss, amounting to 18.32 cubic feet per second. This loss, as will be seen by referring to the first table, is only one-half that reported for the same section in the former series of measurements. In the first series of measurements the quantity of water in the river at the upper end of this section was 132.93 cubic feet per second and the loss was 36.64 cubic feet per second. This loss is 26 per cent of the quantity flowing into this section of the river. In the second series of measurements the loss in this section was found to be 30 per cent. All the sections of the river below show losses varying from 0.62 to 5.45 cubic feet per second per mile in the first series of measurements and from 1.07 to 3.14 cubic feet per second per mile in the second series. In both series the greatest losses are seen to occur in those sections in which the river flows over gravel. A more extended study of the conditions along these sections might locate the places where the greatest losses occur within such narrow limits as to make the improvement of the channel of the river at these places a matter of comparatively little expense.

The following diagram graphically illustrates and compares the gains and losses shown by the two series of measurements made on Big Wood River (fig. 1). In the diagram the scale of miles is so adjusted as to give the approximate distance in miles from Gimlet, the point where the upper measurement in the second series was made.

In the section where a gain was shown the broken line of the diagram slants away from the zero line with a uniform slope, as it is supposed that the gain throughout the section is constant. In those sections where a loss occurs the broken line slants toward the zero line and the loss is supposed to be constant in any single section. The greater the slant of these lines either away from or toward the zero line the greater is the gain or loss indicated. The steps occurring in the broken lines of the diagram represent water flowing in or diverted as the step is away from or toward the zero line.

LITTLE WOOD RIVER AND SILVER CREEK.

Measurements to determine gain or loss from seepage were made on several sections of Silver Creek and Little Wood River. The first measurement was made on August 10 and the last August 31. Assistance was received from J. P. Kosharek, Mathew McFall, J. P. Phippen, and S. P. Richards.

The following tables give the results of these measurements. The distances given in the tables are approximate, being measured along

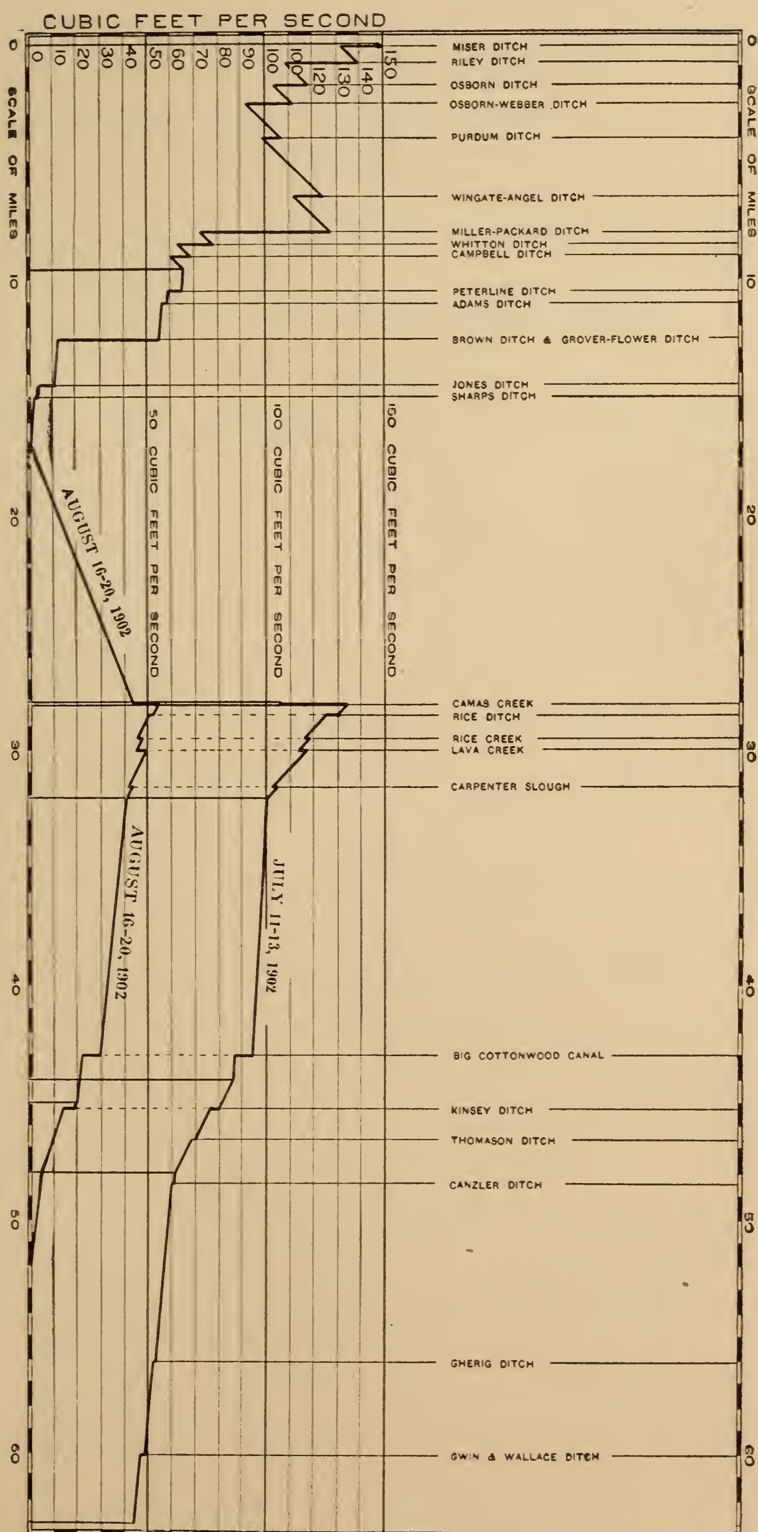


Fig. 1.—Diagram showing gain and loss of water by seepage, Big Wood River, Idaho.

the river channel, and are about double the distance as measured on a straight line between any two points on the river:

Seepage measurements, Silver Creek and Little Wood River, August 10–12, 1902.

[In cubic feet per second.]

FIRST SECTION.

Inflow: Silver Creek at falls at W. A. Hodgman's		60.69
Outflow:		
Diversions in section	1.00	
Little Wood 1 mile below Pagari	52.56	
		53.56
Loss in section		7.13
Length of section ...miles		18.00
Loss per mile		.40
Percentage of loss ...per cent		12

SECOND SECTION.

Inflow: Little Wood 1 mile below Pagari		52.56
Outflow:		
Diversions in section	1.05	
Little Wood at Burn's ranch	50.81	
		51.86
Loss in section		.70
Length of section ...miles		12.00
Loss per mile		.07
Percentage of loss ...per cent		1.00

THIRD SECTION.

Inflow: Little Wood at Burn's ranch		50.81
Outflow:		
Diversions in section	9.26	
Little Wood at Shoshone	34.19	
		43.45
Loss in section		7.36
Length of section ...miles		30.00
Loss per mile		.25
Percentage of loss ...per cent		14.00

FOURTH SECTION.

Inflow: Little Wood at Shoshone		32.39
Outflow:		
Diversions in section	8.60	
Little Wood at McFall's ranch	22.94	
		31.54
Loss in section		.85
Length of section ...miles		7.00
Loss per mile		.12
Percentage of loss ...per cent		2.60

TOTAL SERIES.

Inflow: Silver Creek at falls at W. A. Hodgman's		60.69
Outflow:		
Diversions	19.91	
Little Wood at McFall's ranch	22.94	
		42.85
Loss		17.84
Length of section ... miles		67.00
Loss per mile		.27
Percentage of loss ... per cent		29.00

Seepage measurements, Little Wood River, August 22–23, 1902.

[In cubic feet per second.]

FIRST SECTION.

Inflow: River at McFall's ranch	25.37
Outflow: River at Johnson's ranch	24.15
Loss in section	1.22
Length of section ... miles	6.00
Loss per mile	.20
Percentage of loss ... per cent	5.00

SECOND SECTION.

Inflow: River at Johnson's ranch		24.15
Outflow:		
Diversions in section	13.93	
River below Dwyer Ditch	Dry.	
		13.93
Loss in section		10.22
Length of section ... miles		8.00
Loss per mile		1.28
Percentage of loss ... per cent		42.00

TOTAL SERIES.

Inflow: River at McFall's ranch		25.37
Outflow:		
Diversions	13.93	
River below Dwyer Ditch	Dry.	
		13.93
Loss in section		11.44
Length of section ... miles		14.00
Loss per mile		.82
Percentage of loss ... per cent		45.00

Seepage measurements, Little Wood River, between West Side and East Side ditches, above Carey, August 26, 1902.

[In cubic feet per second.]

Inflow: River 500 feet above West Side Ditch		24.13
Outflow:		
West Side Ditch	6.33	
East Side Ditch	13.86	
River below East Side Ditch	Dry.	
		20.19
Loss in section		3.94
Length of section ... miles		.75
Loss per mile		5.25
Percentage of loss ... per cent		16.00

Seepage measurements, Silver Creek and Little Wood River, August 28–30, 1902.

[In cubic feet per second.]

Inflow: Silver Creek above Kilpatrick Ditch		135.82
Outflow:		
Diversions in section	15.73	
Silver Creek at Picabo-Carey road	119.69	
		135.42
Loss in section		.40
Length of section ... miles		3.00
Loss per mile		.13
Percentage of loss ... per cent		29.00

SECOND SECTION.

Inflow: Silver Creek at Picabo-Carey road		119.69
Outflow:		
Diversions in section	26.06	
Silver Creek at falls at W. A. Hodgman's	87.44	
		113.50
Loss in section		6.19
Length of section ... miles		5.50
Loss per mile		1.13
Percentage of loss ... per cent		5.00

THIRD SECTION.

Inflow: Silver Creek at falls at W. A. Hodgman's		87.44
Outflow: Little Wood at Burns's ranch		66.67
Loss in section		20.77
Length of section ... miles		30.00
Loss per mile		.69
Percentage of loss ... per cent		23.00

FOURTH SECTION.

Inflow: Little Wood at Burns's ranch		66.67
Outflow:		
Diversions in section	27.72	
Little Wood at Shoshone	41.44	
		69.16
Gain in section		2.49
Length of section ... miles		30.00
Gain per mile		.08
Percentage of gain ... per cent		4.00

TOTAL SERIES.

Inflow: Silver Creek above Kilpatrick Ditch		135.82
Outflow:		
Diversions	69.51	
Little Wood at Shoshone	41.44	
		110.95
Loss		24.87
Length of section ... miles		68.50
Loss per mile ... per cent		18.00

Comparing the losses shown by the two series of measurements from the Hodgman ranch to Shoshone it will be noticed from the measurements of August 10–12, that the total loss between these two points is 15.19 cubic feet per second. The flow at Hodgman's being 60.69, the loss is about 25 per cent of the amount where the measurements were commenced. In the series of measurements made August 28–30 the amount of water at Hodgman's is 87.44 cubic feet per second, or an increase of about 44 per cent over the amount found at the same point on August 10. The total loss found on August 28 above Hodgman's is 6.59 cubic feet per second, and the total loss to Shoshone is 24.87 cubic feet per second. Deducting 6.59 from 24.87 leaves 18.28, which represents the total loss between Hodgman's and Shoshone in cubic feet per second. Comparing this with the flow at Hodgman's it is seen that the total loss, while greater in amount, is only about 21 per cent of the quantity at Hodgman's, which is relatively less than the loss in the first instance.

In the first series of measurements the river was measured near Pagari, a station on the Wood River branch of the Oregon Short Line Railroad, and about 18 miles by the river from Hodgman's. The loss in this section is shown to be 7.13 cubic feet per second, and the loss from this point down to the Burns ranch is only 0.7 cubic foot per second, making a total loss of 7.83 cubic feet per second between Hodgman's and Burns's in a distance of some 30 miles. This loss is about 13 per cent of the flow at Hodgman's. In the second series the loss between Hodgman's and Burns's is seen to be 20.77 cubic feet per second, which is about 24 per cent. From this it will be seen that in this section the relative loss in the second series is nearly double, and the absolute loss is nearly three times as great as in the first series of measurements.

In the section from the Burns ranch to Shoshone the loss in the first measurements is 7.36 cubic feet per second. And in the second measurements a gain of 2.49 cubic feet per second is shown in the same section. This discrepancy may be partly accounted for by the fact that the driver who assisted in making the first series of measurements was not familiar with the river, and some ditches that were diverting water might have been overlooked. If this supposition be true, the quantity thus diverted appears in this table as a loss, and on that account the loss shown is greater than it should be.

The greatest losses per mile are shown to occur in the lowest section of the river below Johnson's ranch. The loss here is about 10.22 cubic feet per second in a distance of 8 miles, or about 1.28 cubic feet per second per mile. This loss appears insignificant in comparison with the loss found in Big Wood River, which amounted to nearly 10 cubic feet per second per mile in one instance.

The section in which the next greatest loss occurs is the one next

above Hodgman's, about 5½ miles in length. The loss is shown by the measurements to have been 1.13 cubic feet per second per mile. From these measurements it may be concluded that the losses which occur in Silver Creek and Little Wood River are not great. In order to draw conclusions of greater practical value it would be necessary to extend the measurements over periods embracing a greater variety of conditions.

The losses discovered in the Little Wood River above Carey of 3.94 cubic feet per second, or at the rate of about 5.25 cubic feet per second per mile, are so great as to suggest the value of an artificial waterway for the three-fourths of a mile between the heads of the two ditches that supply water to the ranches along this section of the river.

The accompanying diagram (fig. 2) illustrates the results of the seepage measurements on Little Wood River. The lower broken line on the diagram shows the earlier measurements between Hodgman's ranch on Silver Creek and McFall's ranch on Little Wood River. The upper one represents the measurements made between the head of Kilpatrick's Ditch on Silver Creek and Shoshone and between McFall's ranch and Dwyer's Ditch. The two horizontal scales give approximate distances in miles measured along the river. The vertical scales at the ends of the diagram show cubic feet per second. The vertical lines which touch the scale of miles represent points where the river was measured, the length of the line representing the quantity of water in cubic feet per second found at that point. The slope of the broken lines shows gain or loss in the section between two consecutive river measurements as the slope is away from or toward the bottom of the diagram. The length of the steps occurring at intervals in the broken lines represents the quantity of water diverted by ditches.

EXTENSION OF IRRIGATED AREA.

Between Ketchum and Bellevue lies a fertile valley well adapted to the growth of alfalfa, grain, potatoes, and the hardier fruits. This valley is about 20 miles long and averages about 1 mile in width. About half of this area still awaits development. Below Bellevue where the valley widens out into a triangle of some 12 or 14 miles on a side is a tract containing 30,000 or 40,000 acres. Less than one-fourth of this area is at present irrigated. Below Camas Creek the river flows through a country more or less covered with lava. The irrigated land in this section is found in small isolated areas of irregular outline, lying adjacent to the stream. North of Shoshone some 8 or 10 miles lies a large body of land of great promise containing several thousand acres, and along the lower course of the river on the north side are large areas that would develop under irrigation into splendid ranches. Along Little Wood River northeast of the settle-

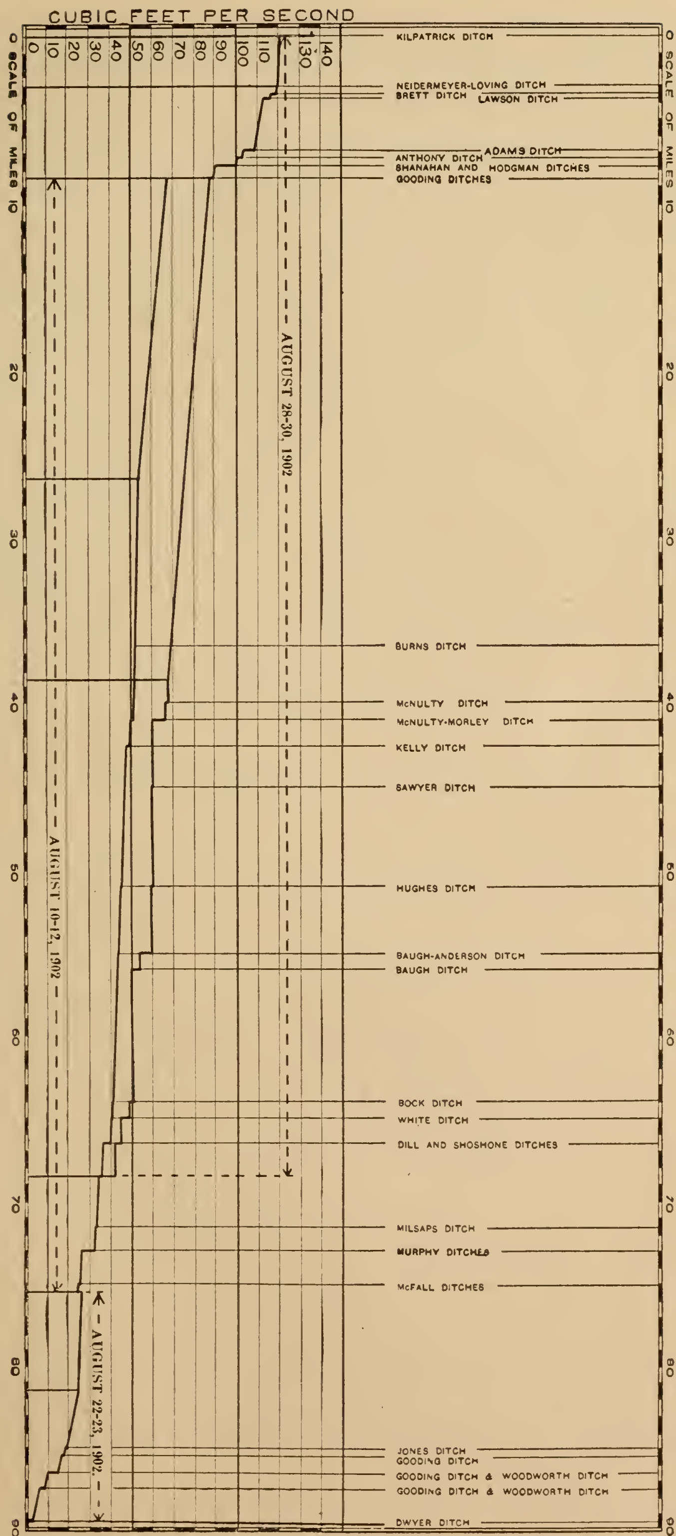


Fig. 2.—Diagram showing gain and loss of water by seepage, Little Wood River, Idaho.

ment of Carey is a tract of several thousand acres still unreclaimed. East of Shoshone and south of Little Wood River along its lower course are large tracts that are susceptible of irrigation. From what has been shown it is evident that more than 50,000 acres could be reclaimed provided an ample water supply could be assured.

The natural water supply of the last two or three seasons has been notably insufficient for the irrigation of the lands which are at present under irrigation. This is due largely to the uneven distribution, the natural supply being greatly in excess of the needs in the early part of the season up to about July 1 and becoming deficient later. In ordinary seasons surplus water to the amount of several hundred cubic feet per second during April, May, and the greater part of June is flowing into the Snake River from these streams. To augment the inadequate natural supply later in the season, the flood waters of spring and early summer could be stored in some of the reservoirs that have been noted. An increased amount of water would also be made available by making improvements in the natural channels in those sections where observations have shown excessive losses from seepage. Especially is this true of Big Wood River below Camas Creek, where in the first series of measurements the total loss was 80 cubic feet per second and in the second series 46.5 cubic feet in a distance of about 25 miles. The conservation of the water supply by storage and the prevention of seepage as suggested would not only insure an ample supply for the area at present under cultivation but would permit the reclamation of new areas.

The feasibility of applying to new lands a large portion of the waters thus made available may be shown by the fact that the lands described are so located as to be readily irrigated from the reservoirs suggested. The Boulder Creek reservoir site being located in the channel of the Big Wood, 10 or 12 miles above Ketchum, the water stored there could be made to serve all of the lands that could be watered from the main stream; more especially it could be used to great advantage on the lands between Ketchum and Bellevue and the lands below Bellevue. This reservoir would act as a regulator, holding back the flood waters and giving them to the stream as required. Its capacity has been stated as nearly 6,000 acre-feet. The Camas Creek site, located in the channel of Camas Creek about half a mile above its confluence with Big Wood River, has an estimated capacity of 10,000 or 12,000 acre-feet. Before this reservoir can be utilized the channel of the Big Wood must be improved in order to prevent the enormous losses found below Camas Creek. Indeed, this improvement alone would be equivalent to an increase of 10,000 or 12,000 acre-feet in the available supply of Big Wood River, as the loss of 80 cubic feet per second below Camas Creek, shown by the measurements of July 11 to 13, would amount to 12,000 acre-feet in about seventy-

five days. If the channel improvements were made the water from the Camas Creek reservoir could be utilized on all lands which can be irrigated from Big Wood River below that point, including the lands adjacent to Little Wood River below where the Big Cottonwood Canal enters the Little Wood. The Hanley Butte reservoir sites are adjacent to the lands described as being on the north side of Big Wood River and some 8 or 10 miles north of Shoshone. The water stored here could be used on these lands and also on lands along the lower river. The reservoir site in the channel of Little Wood River above Carey has an estimated capacity of 15,000 acre-feet. The water that might be stored here, besides being used to supplement the natural supply for the irrigation of lands already under cultivation, could be used to irrigate the new land that lies adjacent to Carey. The total capacity of the reservoirs suggested is about 35,000 acre-feet. This would be sufficient to irrigate about 9,000 acres. If it be assumed that 10,000 acre-feet is required to complete the irrigation of the area that is already cultivated, the balance, or 25,000 acre-feet, would permit the reclamation of 5,000 or 6,000 acres of new land. More observations on the flow of these streams would be necessary in order to determine whether the surplus water would be sufficient to fill the proposed reservoirs. But there is no question that the development of one or more of them would be of great advantage to the people of these valleys.

CLAIMS TO WATER ON BIG WOOD RIVER.

In order to determine what claims had been made to the waters of Big Wood River under the law requiring the posting and filing of claims to water, a careful search was made through the records of Blaine and Lincoln counties. Many of the earlier claims are found in the records of both counties, because of the changes in county lines in later years and the transcribing of the records from the county in which the original records were made. No effort was made to determine the county in which the claim is finally located, but care was taken that the error of counting the same claim twice should not be introduced. The earliest records were made in 1881, there being at that time a law requiring the posting of the notice of appropriation, which law was an almost exact copy of the California law and similar to the one that is at present in force.

It was found that there are 99 claims to the waters of Big Wood River recorded in Blaine County and 20 claims recorded in Lincoln County. Of the 119 notices, 106 claim water for irrigation, 54 for domestic purposes, 31 for general agricultural purposes, 23 for "other useful and beneficial purposes," 16 for milling, 11 for mining, 11 for culinary purposes, 9 for manufacturing, 8 for power, 7 for mechanical purposes, 6 for sale, 5 for watering stock, 2 for ice manufacturing, 2

for storing in reservoirs, 1 for smelting, and 1 for carrying and transporting property.

Many of the claims ignore altogether the provision of the law requiring the claimant to state the place of intended use. Others state that the waters are to be used wherever they can be conducted by the ditch built to convey the same. Fifty-six of the notices give some or all of the dimensions of the ditches. Only four of these claims give the grade of the ditch. So far as the dimensions of the ditches serve as a check upon the amount of water diverted, they are without force and serve mainly to show the ignorance of the claimants in regard to the capacities of ditches.

The larger number of claims use the "miner's inch" or the "inch" without any qualifying term, to express the amount of the claim. Of the 119 claims tabulated, 62, or a little more than 52 per cent, use the term "miner's inch" or the inch measured under a 4-inch pressure. Thirty, or a little more than 25 per cent, state the extent of their claims in "inches" with no qualifying word. Twenty-one, or nearly 18 per cent, use the cubic foot per second as the unit with which to express their appropriation. Three of the claims state the quantity in cubic inches per second, measured under a 4-inch pressure. Two claims use the cubic foot per second under a 4-inch pressure, and one claim states the amount to be diverted in square inches under a 4-inch pressure.

The total amount of the 119 claims, as near as may be estimated, is 22,152 cubic feet per second. It is exceedingly doubtful if the flood flow of Big Wood River ever exceeds one-tenth of this amount, or about 2,000 cubic feet per second, and the normal flow is probably not much greater than one-fiftieth of the total claim or about 400 cubic feet per second.

After the notice has been posted and the copy filed in the office of the county recorder, the claim may be partially or entirely abandoned. This fact is not a matter of record. An analysis of the records will show that they contain but little of value. The record states that a notice, of which it is a true copy, has been posted at or near the point of intended diversion. It gives the use to which the water is to be applied, the amount of water that is to be diverted, a meager description of the ditch, and usually an incomplete description of the land to be irrigated. The only fact stated by the record is that a notice was posted. The balance is made up of what the claimant intends to do. What the claimant intends to do is a matter of consequence to the State only in so far as the appropriation is perfected and the diversion of water to some useful and beneficial purpose becomes a fact. This is a question in which the public is greatly interested, for upon it depends the amount of water that is taken from the stream, the quantity still unappropriated, and the acreage irrigated. These are the important

questions and are the first asked by one seeking a home or an investment. Answers to them can be obtained at present only in a suit at law, where the facts, as stated by the court, rest not upon physical conditions that have been under observation for a period of sufficient length to afford even approximate knowledge, but upon the biased opinions of interested parties.

Section 2625 of the Idaho Code states that "all the waters of the State, when flowing in their natural channels, including the waters of all natural springs and lakes within the boundaries of the State, are declared to be the property of the State, whose duty it shall be to supervise their appropriation and allotment to those diverting the same therefrom for any beneficial purpose." But the State has taken no steps to discharge the duty imposed upon it by this section.

The water rights on Big Wood River have never been adjudicated; the authority of the State, in supervising the allotment has never been exercised on this stream, nor has it been recognized by those diverting its waters. If sufficient water is flowing in the river to permit the ditch to take out the amount claimed, it is diverted and the rights of no other claimant are considered. If the water in the river is so low as to render it impossible to get it into the ditch, the claimant goes without water and hopes for a rise of the river.

There is a decided sentiment among the people of the lower valley of Big Wood River against having their claims adjudicated. The grounds for this sentiment may be briefly stated as follows: During the spring and early summer the lower portion of the Big Wood River has two periods of flood from two to four weeks apart, the earlier flood, as has been stated, coming in from Camas Creek and the latter one from the higher Boulder Mountains. During this period the amount of water carried by the river is more than ample for all demands of irrigation througout the valley. At this time large quantities of water from this stream are discharged through the Malade into Snake River. During this period of plenty, when each irrigator can have all he wishes, there is no need for adjudication and careful distribution of the waters. After this period has passed, the flow of water in the river diminishes so rapidly that the irrigator on the lower course of the river is convinced that the quantity available in the upper stream would not be sufficient to reach him, even were he able to shut the water out of many of the upper ditches. So, rather than become involved in expensive litigation when the outcome promises so little of relief, he decides to take what water he can get and feel thankful that the supply is no less.

DECREES ON SILVER CREEK AND LITTLE WOOD RIVER.

Early in the nineties the water of the Little Wood River was all diverted along the upper section of the stream, leaving none for the

use of the irrigators of the lower portion. As a result of this condition a suit was commenced in the district court of the fourth judicial district of Idaho in 1892. N. R. Woodworth et al. *v.* Frank Anthony et al. was the title of this suit, which resulted in granting decrees to 123 parties on Silver Creek and Little Wood River. The plaintiffs in the case claimed that they were the owners of land near the lower portion of Little Wood River and were entitled to the use of the waters of the river for irrigation and for domestic use; that the defendants were residents of the upper portion of Little Wood River Valley, and that they diverted the waters from the channel of Little Wood River above the lands of the plaintiffs. They further alleged that frequently during the two years next preceding the commencement of this suit defendants had diverted portions, and at times all of the waters of the stream in question to which the plaintiffs were justly entitled, and that on account of this wrongful diversion the channel of the stream in its lower portion was rendered entirely dry except for a few stagnant pools which were unfit for domestic use. The plaintiffs asked that the respective rights of the plaintiffs and defendants be determined and the title to said waters be forever quieted; "that pending this litigation the defendants and each of them be enjoined from diverting from its natural channel and from using any of the waters of said stream to which the plaintiffs are entitled as herein set forth," and "that in the final decree herein, said injunction be made perpetual."

In the answer to the complaint the defendants were divided into two groups, those living in the valley of the Little Wood River above its junction with Silver Creek, and those living on Silver Creek. Each group denied all allegations of plaintiffs, and stated that they were using the water under a right of prior appropriation. Those living along the upper course of the Little Wood River stated further that, except in times of extreme high water, the Little Wood was dry for a number of miles above its junction with Silver Creek; and that if the water diverted by them were allowed to remain in the stream, it would never reach the head gates of plaintiffs' ditches, and for that reason the plaintiffs in this action were not injured by defendants' use of the water. Those defendants located on Silver Creek stated further that Silver Creek has its source in springs rising upon lands owned by them, and flows through the same; that during the irrigating season, "notwithstanding the use of the water thereof by these defendants for the irrigation of the higher portion of their lands, the amount and volume of the waters flowing therein are not diminished, but are actually increased by natural and artifical causes so as to overflow lands of the defendants to their inconvenience, loss, and damage." The statement is also made that the waters of Silver Creek, after entering the channel of Little Wood River, were subjected to such a great loss by

evaporation, sinkage, and seepage that they were lost and did not reach the head gates and ditches of the plaintiffs. The claims set up by the plaintiffs amounted to 32,803⅓ inches and the claims of those defendants whose answers were filed amounted to 28,530 inches, making a total of 61,333⅓ inches, or about 1,227 cubic feet per second.

The facts found by the court at the conclusion of this suit were that the several parties plaintiff had appropriated 4,525 inches, measured under a 4-inch pressure, from the waters of Little Wood River and its tributaries for the irrigation of 6,760 acres owned by them. The land of one of the plaintiffs is not described and no area is assigned to W. C. Hill, who, as one of the plaintiffs, represented the people of the town of Shoshone. It was also found that 11,044 inches, measured under a 4-inch pressure, from the waters of Little Wood River were appropriated by the defendants for the irrigation of 15,960 acres. In this list are found three defendants whose land is not described. The court also found that Silver Creek is a tributary of Little Wood River and that during the low-water season Upper Little Wood River above its junction with Silver Creek is not tributary to Little Wood River below the junction. Thus there are two independent streams included in this adjudication. In the decree, however, there is no separation of the rights of the different streams. They are mingled indiscriminately, so that it is impossible to determine from the decree which stream supplies the water for any particular right. It is only by a comparison of the findings of fact with the map of the valley that one can decide which stream is affected in any particular instance.

The decree stated that the several parties, plaintiffs and defendants, have judgment respectively for the right from the dates given to use for irrigation various definite quantities of water expressed in miner's inches from Little Wood River and its tributaries. It was further stated that the parties to this suit are enjoined from using or in any manner interfering with the water of Little Wood River and its tributaries except as decreed; and that they are enjoined from wasting any of the waters of the stream, and are required to turn all waste water back into the stream at the most practical point, and that the water may be measured in cubic feet per second, according to the plan prescribed by the State engineer, instead of in inches under a 4-inch pressure. This decree was filed July 8, 1895. It gave to the plaintiffs 4,509 inches and to the defendants 10,984 inches, or a total of about 310 cubic feet per second.

The original suit was commenced by the irrigators in the lower valley against the irrigators of the upper valleys, and all those whose crops suffered for want of water came into the case as plaintiffs. There were some irrigators along the middle portion of the river who had all the water they needed and they did not wish to complain of

those above them, so they did not appear among the plaintiffs; neither were they included in the list of defendants. In 1899 a suit was commenced by John W. Dwyer and John A. Boggs, appropriators on the lower portion of the river, against E. S. Morley, John Sawyer, Maggie Burns and her husband J. W. Burns, settlers along the middle course of the river. The result of this suit was a decree filed by the court January 5, 1901, giving to John Sawyer a right to 75 inches of water measured under a 4-inch pressure dating from June 15, 1885. In the fall of 1902 the case was decided in favor of the plaintiffs against the Morley estate, and against the plaintiffs in favor of Maggie and J. W. Burns, who were granted 200 inches under a 4-inch pressure, dating from 1901. By the terms of the decree of 1895 Dwyer and Boggs were given 70 inches from the date of April 1, 1883, and Dwyer was given 15 inches from April 1, 1884. In the last decree they won their case against the Morley estate and were given the 150 inches they claimed, dating from 1883.

In 1902 the case of Frank R. Gooding et al. *v.* Frederick Fator et al. was brought for the purpose of compelling the defendants to accept the decrees to the waters of Silver Creek and Little Wood River that should make the date of their appropriation subsequent to the dates allowed to the plaintiffs in the decree of 1895. Injunctions were served on J. H. Erickson, Frederick Fator, and Adam Ifland, restraining them from using any of the water of Silver Creek for any purpose except for domestic use and for watering stock. J. H. Erickson, in his answer and cross complaint, states that since May, 1882, he has been the owner of and in possession of lot 2 and E. ½ of NW. ¼, sec. 18, T. 5 S., R. 19 E.; that his grantors and predecessors in interest appropriated about 200 inches from Little Wood River for the irrigation of the above-described lands, and that the water has been used continuously since for the irrigation of the lands except when interfered with by the plaintiffs and others. Fator and Ifland claim in their cross complaint that the irrigation of their ranches is by water from Silver Creek that has been running to waste in a sink in the lava beds; that until utilized by them the waste has continued since prior to the memory of any of the settlers on said creek, and that by their efforts this waste has been prevented and the waters applied to beneficial use since about June 7, 1899. This case is still pending.

Another unsettled case is entitled Frost *v.* Mabbutt. It came from an application made by Shelby C. Frost to the district court for a decree granting him the right to the use of the waters of Little Wood River to the extent of 3 cubic feet per second. In this complaint he states that he is the owner of 160 acres of land on the Malade River about 3½ miles below the junction of Big and Little Wood Rivers and 6 or 7 miles below the last irrigation from the Little Wood; that he, his grantors and predecessors in interest have never been parties to

any decree of the waters of Little Wood River, and that the rights to the waters of said Little Wood River have been decreed. The land above described has been irrigated and cropped since June 20, 1882. The claimant states also that since August 29, 1884, he has been in possession of other lands in the same vicinity, of which about 120 acres were under cultivation on September 9, 1899. On August 29, 1884, 3 cubic feet of water per second was diverted for the irrigation of this land. Notice of this claim has been published by the claimant in the Shoshone Independent, in the manner and form directed by law. The claimant prayed the court to take proof of his claim to the right to the use of a proportion of the waters of Little Wood River and its tributaries and adjudge and decree his right to the same. This petition was filed October 31, 1899.

In answer William Mabbutt denied all the allegations made by the claimant, and in the cross complaint made the same claims as in the case of Woodworth *v.* Anthony, in which he was decreed certain rights to the use of the waters of Little Wood River.

This case, more clearly than any yet cited, shows the defects of this method of settling claims to water. In 1899 Frost applied to the district court for a decree granting him the right to the use of the waters of Little Wood River. He claimed that he had made the appropriation June 20, 1882. More than seventeen years elapsed before this claimant felt the necessity of seeking a recognition of his claim through the courts of the State. In the meantime the rights to the waters of the Little Wood had been adjudicated by the courts and given to other appropriators, and the waters of the Big Wood River had been diverted to such an extent as to deplete the river for a long distance above the lands of the claimant. When such a case comes before the court it can not be considered from the view point of the justness of the claimants' right taken in connection with the water supply and the amount of the appropriations already decreed, but, under the practice in Idaho, one whose rights have been decreed must answer and defend the case, thus making it an individual contest. Complainant Frost had an opportunity to enter the suit that resulted in the Wood River decree, but did not avail himself of that opportunity, and the court did not bring him in with all interested parties, as it might have done in that case. Thus we have three independent suits following the case of Woodworth et al. *v.* Anthony et al., all involving rights to the use of the waters of Little Wood River and its tributaries, and claims made prior to the commencement of the above-named suit.

New ranches are being developed and new ditches taken out to supply them with water. The State has taken no steps to prevent these later diversions, although rights to more than the normal flow of the stream have been allotted by the courts. It would seem that the appropriator from a stream whose waters had been adjudicated in the man-

ner prescribed by the laws of the State should receive some protection from the State in the enjoyment of the right which was granted.

DISTRIBUTION OF WATER UNDER DECREES.

The distribution of the waters of Little Wood River under these decrees presents serious physical difficulties. The district is nearly 100 miles long if measured along the river, which is the course over which the water must flow. Early appropriators in the lower 20 miles of the stream must be given water to the extent of about 25 cubic feet per second. To supply this amount at such a distance more than double this quantity must be left in the stream at the upper end of the district. It is difficult for those along the upper portions of the stream to see the justice of permitting such a waste of water in order to supply the earlier appropriators with their decreed amounts, and to enforce this provision of the decree requires no little resolution and force of character on the part of the water master. The water master is an officer of the court appointed for the season and under bonds for the faithful performance of his duties. These duties have proven so arduous that the experience of a single year seems to have been sufficient for each person who has filled the position. The succeeding year finds a new man in the place, who must learn the peculiar conditions of the stream before he can successfully perform his duties. The total amount of water to be distributed is unknown. It is not constant, but changes from day to day, and often the change from one part of a day to another is quite marked. The amount of this fluctuation is a matter of conjecture. The use of measuring devices is not required, and the measurement of the amount diverted is little better than a guess. The length of the district is nearly 100 miles and the gains or losses in this distance have not been determined, yet these unknown quantities must be considered by one who uudertakes the distribution. The people who use the water do not appreciate the difficulties of this task. They realize only that water is delivered to them in insufficient quantities, and their clamor for water adds to the already heavy burden of the water master, so that it is a wonder that his task is performed as well as it is under such conditions.

DECREES ON THE TRIBUTARIES OF BIG WOOD RIVER.

As stated in another part of this paper, no decrees relative to the rights to the waters of Big Wood River have yet been rendered. Rights to the waters of a number of tributaries have, however, been decreed as the result of suits brought by individuals.

The case of McMonigle *v.* Murphy resulted in an adjudication of the rights to the waters of Deer Creek, which flows into Big Wood from the west about 3 miles above Hailey.

It was found by the court among other "facts" that each acre of the plaintiff's land required for its proper cultivation at least 3 inches

of water measured under a 4-inch pressure and that 340 acres of it is capable of cultivation. Following the findings of fact, an order was issued granting to the plaintiff 1,020 inches of water measured under a 4-inch pressure, for the irrigation of 340 acres. This amount of water is recognized in Idaho as being equivalent to 20.4 cubic feet per second, an amount sufficient to cover the 340 acres to a depth of nearly 28 feet during the irrigating season. This decree takes into consideration the claims of the plaintiff and defendant only. In the spring or early summer when the flood waters have subsided to an amount which is estimated by the plaintiff to be equivalent to 1,020 inches, he gives notice to the defendant, who is still attempting to irrigate his ranch by means of the surplus waters. Upon the receipt of the notice the defendant is supposed to close the head gates of his ditches and use no more water during the season. The penalty for refusing to do this would be a suit for contempt of court. The defendant having undergone one such experience seems somewhat reluctant to risk another.

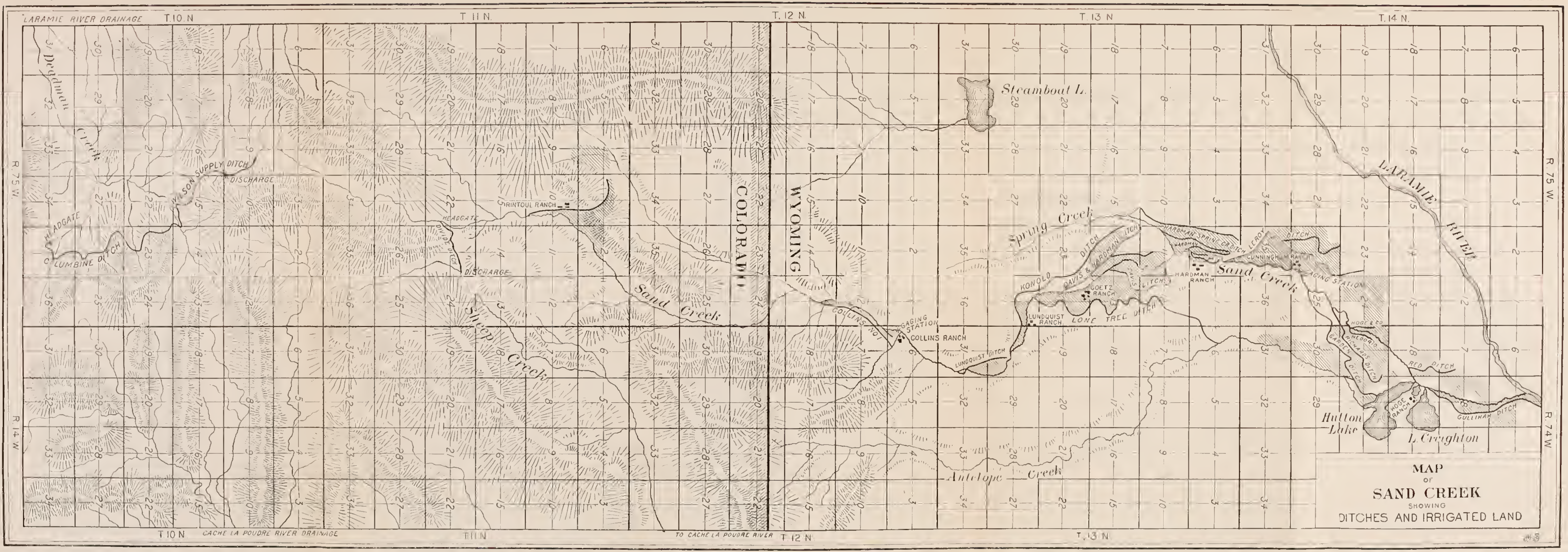
This case more than any other that has come under the notice of the writer suggests the necessity of basing the claims to the use of water upon reliable information about the quantity of water flowing in a stream and the area it can be made to irrigate. It is the privilege of the people to insist that rights to water be so granted and the supply so distributed and used that the greatest possible benefit may be conferred upon the Commonwealth. It is readily seen that the future development of the State will receive a serious check if in granting decrees the interests of the State are not considered. There are other lands in Deer Creek Valley that are susceptible of development under irrigation. The improvement of these lands would mean the building of more homes, an increase in the population of the State, an increase in the taxable property of the State, and a greater amount of agricultural products or of stock to be marketed. An increase of the wealth-producing power of the State would result in greater general prosperity. Under the Big Ditch in Wood River Valley, 3 miles below McMonigle's Deer Creek ranch, 1 inch per acre is deemed sufficient for the needs of growing crops. The soil is gravelly with a porous subsoil, and probably requires as much water per acre for the irrigation of crops as does that in Deer Creek Valley. The 1,020 inches decreed should serve 1,020 acres instead of 340 acres. In Deer Creek Valley there can be no further development so long as this decree stands.

The case of the City of Bellevue *v.* Simpson Goble et al., resulted in giving to the city of Bellevue a decree for 300 inches, measured under a 4-inch pressure, of the waters of Seamands Creek as against the defendants; and the defendants were enjoined from interfering in any manner whatever with that amount of water. This decree was given under date of November 9, 1885. On June 2, 1886, the decree was modified so as to allow the city of Bellevue 150 inches of water. There

were nine defendants in the case, but their respective rights were not settled.

In 1891 a suit was brought by Simpson Goble against Jennie Galbraith and Asa Kimbrough to determine the rights of these parties to the waters of Seamands Creek. This case was settled by the three interested parties entering into a contract to divide equally among themselves the water remaining after the claim of the city of Bellevue to 3 cubic feet per second had been satisfied. In 1900 each of the parties to this contract, having sold his interest in the land and water rights, a suit was brought by M. J. Daly et al. against Torresto A. Josslyn, on account of troubles arising over the division of the water. In this case it was the judgment of the court that the contract was binding upon the former owners and also upon their successors in interest, and a decree was rendered in accordance with the judgment.

The suit of the Idaho and Oregon Land Improvement Company, Alturas Water Company, and Jabez Chase *v.* S. M. Tucker and George H. Knight was brought to determine the rights of the respective parties to the waters of Indian Creek, a small stream flowing into the Wood River Valley a few miles above Hailey. The normal flow of the creek sinks before reaching Wood River. The case was tried in May, 1886. A decree for 86 inches measured under a 4-inch pressure was given to defendants and the water remaining was granted to the plaintiffs. The defendants were enjoined from diverting more than 86 inches measured under a 4-inch pressure. The decree and the injunction were filed February 18, 1888. A notice of this decree was served on S. M. Tucker in June, 1898, twelve years subsequent to the date of the trial. In 1889 it was made to appear to the judge of the fourth judicial district of Idaho that the services of a water master were necessary on Indian Creek to enforce the terms of the decree, and a water master was appointed June 21, 1899. His labors resulted in having S. M. Tucker cited for contempt of court on July 8, 1899. Growing out of this case was the suit entitled A. Caldwell and Alturas Water Company *v.* S. M. Tucker et al. for the settlement of the rights to the use of waters of Indian Creek. A. Caldwell represented the Idaho and Oregon Land Improvement Company and the parties interested were the same as in the suit that was tried in May, 1886. The case was tried in 1900 and resulted in a decree granting to Nancy M. Tucker, the widow of S. M. Tucker, all the waters of Indian Creek, and the judgment "that neither of the plaintiffs has any right, title, or interest in or to said water or any part thereof." The former decree granted to defendants 86 inches and all the balance to the plaintiffs. The latter decree granted all the water to defendants and none to plaintiffs. The question of title to the waters of Indian Creek is still in a very chaotic state. The cases of litigation on Indian Creek afford a good illustration of the difficulty of forever quieting title to water under the existing laws of Idaho.


LARAMIE RIVER DRAINAGE
T. 10 N.
T. 11 N.
T. 12 N.
T. 13 N.
T. 14 N.
R. 75 W.
R. 74 W.
R. 75 W.
R. 74 W.
Dredman Creek
HEADGATE
COLUMBINE DITCH
WILSON SUPPLY DITCH
DISCHARGE
HEADGATE
DIVIDE DITCH
DISCHARGE
RINTOUL RANCH
Sheep Creek
Sand Creek
COLORADO
WYOMING
Steamboat L.
COLLINS NOT
GAGING STATION
COLLINS RANCH
LUNDQUIST DITCH
LUNDQUIST RANCH
LONE TREE DITCH
KONOLO
DAVIS & HARDMAN DITCH
GOETZ RANCH
Spring Creek
HARDMAN SPRING CR. DITCH
HARDMAN RANCH
LEROY
CUNNINGHAM RANCH
GAGING STATION
Sand Creek
LARAMIE RIVER
HOGE & CO.
GARDNER DITCH
RED DITCH
HOGE RANCH
GULLIHAN DITCH
Hutton Lake
L. Creighton
Antelope Creek
T. 10 N.
CACHE LA POUDRE RIVER DRAINAGE
T. 11 N.
TO CACHE LA POUDRE RIVER
T. 12 N.
T. 13 N.
MAP OF SAND CREEK SHOWING DITCHES AND IRRIGATED LAND

IRRIGATION INVESTIGATIONS ON SAND CREEK, ALBANY COUNTY, WYO.

By Burton P. Fleming,
Irrigation Engineer, University of Wyoming.

INTRODUCTION.

The object of the investigation carried on in the watershed area of Sand Creek during the season of 1902 was to determine, if possible, just how the water supply is utilized in a district where agricultural conditions are typical of those at present existing in southern Wyoming, and to investigate and report upon those economic conditions which in any way affect the utilization of the water supply in such a district. Although the season proved to be somewhat unusual and although other conditions tended to make the result show an extreme rather than the normal, still it is thought that in its location, history, climate, agricultural resources and possibilities, and in the problems which its residents have to face the district chosen was quite typical.

The watershed of the stream lies partly in Wyoming and partly in Colorado. The larger and cultivated portion lies near the southern boundary of Wyoming, in the southern part of Albany County, and forms a part of the elevated table-land known as Laramie Plains. The remaining portion of the district, which is largely mountainous, lies in the north central part of Larimer County, Colo. The course of the stream is shown by the map (Pl. VI). It joins the Laramie River about 15 miles southwest of the city of Laramie.

Irrigation on Sand Creek commenced about 1869. This date also marks the beginning of the live-stock industry upon the Laramie Plains. While the adaptability of the country for stock raising had long been recognized, its remoteness from markets and the presence of hostile Indians materially retarded development. The completion of the Union Pacific Railroad as far as Laramie, in 1868, helped to remove these difficulties, and many persons immediately engaged in the stock business. Cattle were at first allowed to shift for themselves, both winter and summer, without other attention than the annual round-up, but heavy losses during severe winter weather from cold and starvation soon convinced many of the more progressive cattle owners of the necessity of providing forage for winter feeding. They

therefore began to acquire tracts of land along the stream bottoms subject to annual overflow, from which they cut small quantities of native hay. The first of such ranches along Sand Creek was that belonging to Charles Hutton. His ranch extended for some distance along the Laramie River and embraced merely that portion of the Sand Creek bottoms immediately adjacent to that river. Probably 1,000 acres were irrigated from Sand Creek. The method of irrigation was simple. Dams of timber and of brush and rock were built in the creek and the water raised till, by the aid of wing dams on either side of the channel, it was spread out over the creek bottoms, which in many places are quite flat. The hay grown upon these meadows was stacked in the field and in winter was fed to cattle in the open. The history of the locality follows that of similar localities throughout Wyoming. The owner of the original ranch, by investing too heavily in cattle during the inflation in the price of live stock in the few years following 1880, became bankrupt when the general collapse in prices came in 1884. The original ranch was divided up into a number of smaller holdings, other ranches were established upon the stream above the first, and with the increase in population and the depletion of natural pasturage the great stretch of free range on either side of the creek was gradually fenced in.

The resources and possibilities of the region in the line of agriculture are limited almost entirely to the raising of forage for the winter feed of cattle. Stock raising necessarily is and must continue the main industry. The altitudes of the ranches are from 7,500 to 9,000 feet above sea level. The winters are long, dry, and cold. The summers are short, with hot days and cold nights. Frost may be expected any month in the year. The annual rainfall in the cultivated portions is not much over 10 inches in depth, of which half often falls during the fall and winter months. Nothing can be grown without irrigation, and the crops capable of growth under irrigation are limited to the more hardy cereals, potatoes, and forage crops, such as peas, roots, alfalfa, and native hay.

In such a district as this, where the industry is of the simplest character, it might be expected that the economic questions confronting the landholders would likewise be simple. As a matter of fact, however, the questions are many and perplexing. The industry being stock raising, the question of first importance must, of course, be that of providing food for stock. Forage crops having to be grown under irrigation, the usual question is encountered as to the most equitable means of distributing water, and this question will be equaled in importance in a few years by that of how best to utilize the water supply which is constantly increasing in value. Of great importance in the district at present is the question of the interstate water rights. A case involving such rights is now pending in the United States courts.

The range problem is also one which vitally concerns not only this particular district, but also like localities in all parts of Wyoming to-day. Many of these problems can never be solved satisfactorily by the people themselves, because of the numerous complications involved, and must ultimately depend for their complete solution upon action by the State and Federal governments.

THE WATER SUPPLY.

CHARACTER OF THE WATERSHED AND RAINFALL.

As shown by the map (Pl. VI), Sand Creek rises in a very mountainous country. The upper slopes of the mountains, being at an elevation of from 9,000 to 11,000 feet and as yet not devastated by fire, are covered with a very thick and continuous forest growth. The snowfall being large, these forests aid materially in keeping up the summer flow of the stream. That portion of the watershed lying in Wyoming and a small part of that in Colorado are entirely destitute of forest growth, or, in fact, of any vegetation whatever, except the small amount of grass and sagebrush growing on the hill slopes. Rains in the lower portion of the watershed are therefore accompanied by almost immediate rises in the stream.

Of the annual precipitation in the mountainous portion of the watershed no data is extant, but it probably differs but little from that determined at the places noted,[a] which is on the average about 16 inches. The precipitation in the lower portions of the watershed probably does not differ greatly from that at Laramie, about 15 miles distant. At Laramie the average annual precipitation during a period of eleven years has been 10.5 inches.

The area of the mountainous portion of the watershed is about 36.25 square miles, of the remainder about 47.5 square miles.

FLOW OF THE STREAM.

Unfortunately no data are available on the flow of the stream previous to this year. Two gaging stations were established upon the creek in October of 1901, at which daily gage readings were made from that time up to October of 1902. The first of these stations was established a short distance below the Colorado-Wyoming line, practically above all the irrigated land in Wyoming. The other was established as near the mouth of the creek as possible. By reason of the character of the channel it had, however, to be placed above the Hoge ranch, the largest on the stream. In the following table are given

[a] Average precipitation at Longs Peak Station during five years, 16.48 inches. Average precipitation at Moraine Station, Colo., during eleven years, 17.48 inches. Average precipitation at Waterdale Station, Colo., during five years, 16.60 inches. (See U. S. Dept. Agr., Office of Experiment Stations Bul. 118.)

the discharges of the creek at each of the gaging stations in acre-feet per month during the time that gagings were made. The past season was exceptionally dry, and the flow of the creek was further diminished by recent diversions of its waters above the gaging stations. The flow as given by the table does not, therefore, represent the average in normal years, but rather the lowest extreme. It is quite probable that the stream never gets lower than it did during the season of 1902.

Total monthly discharge of Sand Creek from October, 1901, to September, 1902.

Month.	Upper station.	Lower station.	Month.	Upper station.	Lower station.
1901.	*Acre-feet.*	*Acre-feet.*	1902—Continued.	*Acre-feet.*	*Acre-feet.*
October	207.53	223.60	March	150.00	250.00
November	209.57	505.03	April	521.80	416.29
December	100.00	150.00	May	1,044.60	269.19
			June	168.90	211.00
1902.			July	117.02	118.40
January	100.00	150.00	August	62.20	55.60
February	150.00	200.00	September	64.20	61.00

STORAGE POSSIBILITIES.

Intimately connected with the consideration of the water supply is the question of storage sites, and particularly is this question of interest in the district under consideration because of the shortage of water last summer and the possibility of a recurrence of the condition in the future.

For the first 15 miles of its length Sand Creek has a very rapid fall, and water could be stored only at great expense by reason of the height of dam required. After passing the Wyoming-Colorado boundary, however, the fall is greatly diminished and it is a few miles north of the boundary line that the first reservoir site is found. The site was surveyed by the writer, and seems to present unusual opportunities for storing a comparatively large body of water at small expense. With a 45-foot dam the capacity would be 2,500 acre-feet, and with a slight increase in height of dam the capacity could be greatly increased. The dam would have to be of composite character, rock-filled with earth facing, both of which materials could be found on the site. Assuming an average flow of 500 acre-feet per month in normal seasons, it is seen that about five months' flow of the stream would be required to fill the reservoir.

Another site is found farther down the stream in one of the natural basins common on the Laramie plains. This site, while not requiring as high a dam, would, it is thought, require quite as expensive operations to get the water out after once impounding it as it would to construct the dam at the previous site. The estimated capacity of this site is 1,000 acre-feet. Other sites are found farther down the stream, but too far down to be of material benefit to the users of Sand

Creek water. It must be expected, however, that any reservoir in the Sand Creek Valley will suffer large losses by seepage because of the porous character of the soil and rock. The prevailing geological formation in the valley is a light and very porous sandstone, which disintegrates rapidly upon exposure to moisture.

DISTRIBUTION AND USE OF WATER.

WATER RIGHTS.

Water rights upon Sand Creek have not, up to the present time, been established in accordance with the Wyoming statutes. In 1894 the State board of control undertook the determination of rights on the stream, and to that end the claims of the several appropriators were filed, the ditches surveyed and mapped, and the areas of land under each of the ditches found. The stream priorities of the several ditches were also established. Sand Creek is, however, a tributary of the Laramie River, upon which the water rights have not yet been adjudicated. Contests were filed against the claims of the Sand Creek appropriators by claimants on the Laramie River, and consequently the rights on Sand Creek could not be finally and officially established prior to the adjudication of rights on the main stream.

The following table gives the result of the adjudication of the rights on Sand Creek made by the State board of control in 1894:

Appropriations from Sand Creek.

Stream priority.	Name of ditch.	Name of appropriator.	Post-office address.	Date of appropriation.	Use for which appropriation made.	Area irrigated.	Description of lands irrigated.
						Acres.	
2	James Hardman	James Hardman	Laramie	1878	Irrigation, stock, and domestic.	127	SE. ¼ SW. ¼, 15 acres; SW. ¼ SE. ¼, 32 acres; NW. ¼ SE. ¼, 40 acres; SW. ¼ NE. ¼, 40 acres, sec. 2, T. 13 N., R. 75 W.
3	Gullihan Ditch	J. M. Hoge	do	1880	Irrigation	224	W. ½ NW. ¼, 80 acres; NE. ¼ NW. ¼, 40 acres; SE. ¼ NW. ¼, 26 acres; NE. ¼ SW. ¼, 10 acres; NW. ¼ SW. ¼, 40 acres; SW. ¼ SW. ¼, 10 acres; SE. ¼ SW. ¼, 18 acres, sec. 8, T. 14 N., R. 74 W.
3	Red Ditch	do	do	1880	do	207	NE. ¼ SE. ¼, 25 acres; NE. ¼, 160 acres, sec. 18. SW. ¼ SW. ¼, 22 acres, sec. 8, T. 14 N., R. 74 W.
1	Gullihan, No. 2	Wyoming Central Land and Development Co.	do	1871	do	196	NE. ¼ NW. ¼, 3 acres; SE. ¼, NW. ¼, 32 acres; SW. ¼ NW. ¼, 5 acres; E. ½ SW. ¼, 80 acres; SW. ¼ SW. ¼, 40 acres; NW. ¼ SW. ¼, 36 acres, sec. 5, T. 14 N., R. 74 W.
1	Braden Ditch	do	do	1871	do	92	NE. ¼ NW. ¼, 16 acres; lot 1, 38 acres; lot 2, 20 acres; lot 3, 18 acres, sec. 19, T. 14, R. 74.
1	Nedart Ditch	do	do	1871	Irrigation and domestic.	122	Lot 3, 20 acres; NE. ¼ SW. ¼, 20 acres; SE. ¼ NW. ¼, 40 acres; NE. ¼ NW. ¼, 24 acres; lot 2, 18 acres, sec. 19, T. 14 N., R. 74 W.
1	Red Ditch	do	do	1871	Irrigation	73	NW. ¼ NW. ¼, 40 acres; SW. ¼ NW. ¼, 33 acres, sec. 17, T. 17, R. 74.
4	Gullihan, No. 1 Ditch	J. M. Hoge	do	1882	do	176	SE. ¼ SW. ¼, 22 acres; NE. ¼ SW. ¼, 30 acres; SE. ¼ NW. ¼, 14 acres; NW. ¼ SE. ¼, 30 acres; SW. ¼ NE. ¼, 39 acres; NW. ¼ NE. ¼, 37 acres; NE. ¼ NE. ¼, 4 acres, sec. 8, T. 14, R. 74. SW. ¼ SE. ¼, 17 acres; NW. ¼ SE. ¼, 5 acres; SW. ¼ NE. ¼, 10 acres; NW. ¼ NE. ¼, 22 acres; NE. ¼ NW. ¼, 12 acres; SE. ¼ NW. ¼, 4 acres, sec. 5, T. 14, R. 74.
1	do	Wyoming Central Land and Improvement Co.	do	1871	do	118	NE. ¼ NW. ¼, 6 acres, sec. 17, T. 14, R. 74. SE. ¼ SE. ¼, 10 acres; SW. ¼ SE. ¼, 32 acres, sec. 32, T. 15, R. 74.
4	Le Roy Ditch	Robert J. Gardiner	do	Oct., 1883	do	480	NW. ¼ SW. ¼; NE. ¼, sec. 24, T. 14, R. 75.
5	do	Peter Cunningham	do	May 1, 1885	do	605	All of sec. 26, T. 14, R. 75, except 15 acres in SE. ¼ SE. ¼ and 20 acres in NW. ¼ NW. ¼ sec. 26.
6	Davis Bros., No. 1	John Goetz	do	Spring, 1885	Irrigation and stock, 200 head.	256	SE. ¼ NE. ¼, 20 acres; NE. ¼ NE. ¼, 40 acres, sec. 14. NW. ¼ NW. ¼, 32 acres; NE. ¼ NW. ¼, 12 acres, sec. 13. W. ½ SW. ¼, 80 acres; SE. ¼ SW. ¼, 12 acres, sec. 12. NE. ¼ SE. ¼, 30 acres; SE. ¼ SE. ¼, 30 acres, sec. 11, T. 13, R. 75.
7	Le Roy Ditch	Riverside Live Stock Co.	do	do	do	318	SW. ¼ SE. ¼, 30 acres; NW. ¼ SE. ¼, 40 acres; NE. ¼ SE. ¼, 8 acres; NE. ¼ SW. ¼, 15 acres; NW. ¼, 160 acres; W. ½ NE. ¼, 80 acres; NE. ¼ NE. ¼, 15 acres, sec. 35, T. 14, R. 75.
8	W. Konold Ditch	William Konold	do	Apr., 1886	Agriculture, irrigation, and culinary.	320	SE. ¼, S. ½ NW. ¼, N. ½ SW. ¼, SE. ¼ SW. ¼. Sec. 14, T. 13, R. 75 (also 320 acres sec. 30, T. 15, R. 74).
8	do	N. Lundquist	do	1886	Irrigation	78	SE. ¼ NW. ¼, 15 acres; SW. ¼ NW. ¼, 18 acres, sec. 30, T. 13, R. 74. SE. ¼ NE. ¼, 15 acres; SW. ¼ NE. ¼, 30 acres, sec. 25, T. 13, R. 75.

9	Collins, No. 4	F. B. Collins	....do	Apr., 1887	....do	26	NW. ¼ NW. ¼, 4 acres, sec. 7; SW. ¼ SW. ¼, 18 acres; NW. ¼ SW. ¼, 4 acres, sec. 6, T. 12, R. 74.
1	Richards Ditch	Wyoming Central Land and Development Co.	....do	1871	....do	250	NE. ¼, 160 acres; NW. ¼ SE. ¼, 22 acres. NE. ¼ SW. ¼, 20 acres; SE. ¼ SW. ¼, 28 acres; lot 4, 20 acres, sec. 19, T. 11, R. 74.
10	....do	....do	....do	1888	....do	45	NW. ¼ NW. ¼, 10 acres; SW. ¼ NW. ¼, 20 acres, sec. 20, T. 14, R. 74. SE. ¼ SE. ¼, 15 acres, sec. 18, T. 14, R. 74.
11	Davis Bros., No. 2	John Goetz	....do	May, 1890	Irrigation, stock, and domestic.	220	SE. ¼ SE. ¼, 20 acres; NE. ¼ SE. ¼, 20 acres; NW. ¼ SE. ¼, 10 acres; SW. ¼ NE. ¼, 20 acres; NW. ¼ NE. ¼ sec. 14; SW. ¼ SE. ¼, 20 acres, NW. ¼ SE. ¼, 30 acres, sec. 11. SW. ¼ NW. ¼, 15 acres; SE. ¼ NW. ¼, 5 acres; NW. ¼ NW. ¼, 25 acres; SW. ¼ SW. ¼, 15 acres, sec. 13, T. 13, R. 75.
12	Lone Tree Ditch	....do	....do	Mar., 1890	Irrigation and stock	398	SE. ¼ SW. ¼, 25 acres, NE. ¼ SW. ¼, 35 acres; SE. ¼ NW. ¼, 35 acres; NE. ¼ NW. ¼, 40 acres; NW. ¼ NE. ¼, 30 acres; SW. ¼ NE. ¼, 30 acres, sec. 24. SW. ¼ SW. ¼, 25 acres; SE. ¼ SW. ¼, 25 acres; NW. ¼ SW. ¼, 40 acres; NE. ¼ SW. ¼, 38 acres; SW. ¼ NW. ¼, 40 acres; SE. ¼ NW. ¼, 20 acres; NE. ¼ NW. ¼, 15 acres, sec. 13, T. 13, R. 75.
13	Collins Ditch	F. B. Collins	....do	1890	Irrigation	55	NW. ¼ NW. ¼, 18 acres, sec. 7. NE. ¼ NE. ¼, 5 acres; SE. ¼ NW. ¼, 10 acres; NE. ¼ NE. ¼, 5 acres; NW. ¼ SE. ¼, 7 acres; SW. ¼ SE. ¼, 10 acres, sec. 12, T. 12, R. 73.
14	Davis Bros., No. 2, and Alice Hardman.	Alice Hardman.	....do	Aug. 8, 1891	Irrigation and stock	320	W. ½ SW. ¼, 80 acres; NE. ¼ SW. ¼, 40 acres; NW. ¼, 160 acres; NW. ¼ NE. ¼, 40 acres, sec. 2, T. 13, R. 75.
15	Lone Tree and Antelope.	J. M. Hoge	....do	Mar. 17, 1894.	Irrigation and domestic.	410	E. ½ SW. ¼, 80 acres; NW. ¼ SE. ¼, 35 acres; SE. ¼ NW. ¼, 40 acres; NE. ¼, 160 acres, sec. 30, T. 14, R. 74. NW. ¼ SW. ¼, 23 acres; NE. ¼ SW. ¼, 30 acres; SW. ¼ NW. ¼, 20 acres; lot 2, 30 acres, sec. 20, T. 14, R. 14. NE. ¼ NW. ¼, 25 acres; lot 1, 20 acres; lot 2, 20 acres; lot 3, 20 acres, sec. 31, T. 14, R. 74. SE. ¼ SE. ¼, 40 acres, sec. 19, T. 14, R. 74.
16	Davis Bros., Sand Creek No. 2.	Alice Hardman	....do	Nov. 26, 1894.	Irrigation	125	NW. ¼, 120 acres; NW. ¼ NE. ¼, 5 acres, sec. 11. NW. ¼ NE. ¼, 5 acres, sec. 11. N. ½ NW. ¼, 80 acres; SW. ¼ NW. ¼, 30 acres; SE. ¼ NW. ¼, 10 acres, sec. 11, T. 13, R. 75.

Under the provisions of a law passed by the Wyoming legislature in 1903, water rights can be established on a tributary prior to the adjudication of rights upon the main stream, but are subject to contest by claimants of earlier rights upon the main stream. This will allow of the final establishment of Sand Creek rights at an early date, subject, of course, to future contest by earlier appropriators on the Laramie River.

No water commissioner has, up to the present time, had jurisdiction upon Sand Creek. Conditions found in the district can not, therefore, be said to be indicative of the advantages or defects of the Wyoming law relating to the distribution of water in its practical working. Up to the past season no very serious scarcity of water has been experienced. Each appropriator has been able to get sufficient water to mature his crops, though probably in many instances it was not all he would have desired to use. As has been said, however, the season of 1902 was characterized by an unusual scarcity of water. Under such a condition the disadvantage of having no disinterested person to apportion the water upon some established basis became plainly apparent. While there is a tacit understanding and recognition of their respective rights by the several ranchmen, but little attempt was made by any of them to limit the amount of water he diverted from the stream. Being bound together by a more or less close community of interest, the ranchmen with earlier rights were not eager to enforce these rights against their neighbors, and the consequence was that some of the later appropriators obtained water to which technically they had no title. It is doubtful, however, if conditions would have been greatly different if a water commissioner had been given control of the distribution of the supply. In other districts with which the writer is acquainted nearly the same conditions prevail. Water has not become so scarce that its value is very highly appreciated. It is seldom measured at its point of diversion from the stream, and when measured, the methods in most instances are crude and inaccurate. The water commissioner is usually a resident of the district over which he has jurisdiction. By too strict and conscientious an observance of his duties he is liable to get into disrepute with those of his neighbors who possess inferior rights, and, on the other hand, if not strict enough he will incur the enmity of the owners of early rights. The position is usually one in which a neutral course is impossible, or at best very hard to maintain, and the compensation is insufficient to justify a man in neglecting his private affairs to give his undivided attention to the settlement of those difficulties which arise. The situation therefore becomes so entirely unpleasant for him that unless he be a man of unusual hardihood and determination he usually gives up the office. Such a state of affairs is naturally very detrimental to the interests of the community and would tend in the end to defeat one of the objects

upon which the Wyoming law is based—that is, the equitable division of water according to vested rights.

One problem which must be solved before any method of distribution can be rendered effective is to find the proper amount of water to apply to hay meadows.

DUTY OF WATER.

During the past season a beginning was made in the determination of the amount of water actually used upon hay meadows. It is necessary to repeat, however, that the results show conditions in dry years rather than during ordinary seasons, and can not therefore be made the basis of very trustworthy conclusions as to normal conditions. As before stated, two stations were established upon the stream at which continuous measurements were made during the season. Between these stations seven ditches are taken out. It was thought that by keeping a continuous gaging of the flow in each of the ditches and likewise of the flow of the stream at the two gaging stations a very close determination of the amount of water used could be obtained. Arrangements were made with ranchmen living near the head gates of the different ditches to make gage readings at frequent intervals, particularly when for any reason the flow in the ditch increased or decreased. The several gentlemen with whom the arrangement was made conscientiously performed their part of the work, and it is thought that the results are fairly accurate. The measurements were made by weirs in cases where the necessary fall could be obtained, but as in most of the ditches the fall is very slight a section of the ditch about 25 feet long was straightened and evened on either side of the gage, and a number of measurements made by current meter with different depths of water in the ditch, a rating thus being obtained.

The total daily discharge in the seven ditches is shown graphically in fig. 3.

The following table gives the flow in all of the ditches mentioned:

Discharge of ditches between Upper and Lower gaging stations, Sand Creek, Wyoming.

Ditch.	Discharge in acre-feet.				Total.	Area under ditch.[a]	Acre-feet per acre.
	April.	May.	June.	July.			
						Acres.	
Lundquist	0.00	33.49	18.96	0.00	52.45	132	0.40
Konold	29.50	153.49	33.48	35.49	251.96	398	.63
Lone Tree	14.00	447.50	59.20	57.12	577.82	398	1.45
Davis & Hardman	.00	81.39	.00	.00	81.39	480	.17
Davis	.00	66.84	15.00	.00	81.84	256	.32
Hardman	53.20	229.61	101.72	9.60	394.13	127	3.10
Leroy	.00	109.64	.00	.00	109.64	605	.18
Total	96.70	1,121.96	228.36	102.21	1,549.23	2,396	....

[a] Total area under ditch. Actual area to which water was applied impossible of determination.

From the above data it is seen that 1,549.23 acre-feet was diverted from Sand Creek and used in the seven ditches in which measurements were made. From data supplied by the ranchmen whose lands are watered by these ditches it is found that the yield of hay was approximately 160 tons. Probably much more could have been grown had the same amount of water been supplied to a smaller area. As each man had to have some share of the supply it was distributed over such a large area that it did little good anywhere. In most cases a growth of grass was obtained which would make winter pasturage for cattle. As calculated from the above data the average depth to which water was applied to the land was 0.646 foot or 7.75 inches. Meadow hay estimated upon the value returned in feeding cattle is worth about $10

FIG. 3.—Diagram showing discharge of ditches from Sand Creek.

per ton. Upon this basis the value of water per acre-foot is seen to be about $1. Low as this may appear to be it is probably not far from the average value returned from the use of water upon such lands. The Hardman Ditch has the earliest right upon the stream. During the past season its flow was probably more nearly at the normal than any of the other ditches. As can be seen from the above table a total amount of 394.13 acre-feet was used under this ditch during the season. The area irrigated was about 127 acres. Undoubtedly much of the water applied almost immediately returned to the stream, as the land borders upon the creek and the soil is of a very porous character. Based upon actual measurements the total depth to which water was applied was 3.10 feet. The yield of hay from this area of 127 acres was about 20 tons. Its value would be about $200, which would give

to water used upon this meadow a value of about 50 cents per acre-foot. The above yield is far below the average, although the amount of water used was about the same as during average years. Mr. Hardman explains the circumstance as the result of his having had to shut off the water for about ten days during the month of May. He states that the grass then received a setback from which it failed to recover. The usual crop is in the neighborhood of 1 ton to the acre, which would make the value of the water in normal years about six times that found above.

It would seem, however, that none of these results represent the value of water as used in the entire district according to the estimates of the pecuniary loss due to the shortage of water during the past season. But, whatever may be the value of water so used, from an economic standpoint the present method of using water upon the hay meadows appears to be extremely wasteful. The land is seldom if ever smoothed and leveled to facilitate irrigation. Contour ditches are often run to the higher knolls, but the usual practice is to bring the water to the highest portions of the land irrigated and then let it run for several weeks continously without attention. The natural result is that the low-lying portions of the meadow are flooded, while the higher portions are left completly dry except for such moisture as rises from the lower portions. Many of the meadows were originally range or dry pasture lands which have been transformed into meadows by the application of water. The native grasses which are common to such land, and which probably would be greatly stimulated in growth by a moderate amount of water, are literally "drowned out" by the excessive amounts applied in actual practice. These native grasses, such as needle grass, prairie June grass, and various species of blue and wheat grasses, are very nutritious and valuable as forage, but they can not thrive in the presence of such an excess of moisture, and their places are taken by vegetation suited to moist and alkaline locations. Such are foxtail, tussock grass, alkali meadow grass, weeds of doubtful value, as parsnip, plaintain, Beckmannia, alkali saccaton, etc., while in the continually wet places sedges of various species, wire grass, and bullrushes thrive. The latter class of vegetation certainly makes anything but desirable hay; yet the endeavor of nearly all ranchmen is to put such an amount of water upon their meadows as will completely submerge, or at least thoroughly soak, the entire area, high places included. Unless this can be done complaints are heard over the shortage of water. Undoubtedly this flooding tends to give a quantity of hay and there are some who claim that excessive amounts of water are necessary to grow any crop whatever at high elevations. While this may be true to some extent, it certainly would appear that a smaller quantity of better hay to the acre than now grown would be something very desirable, and it is possible that a meadow irrigated with moderate amounts of water and with

some care and attention in irrigation might in the end give as high a yield of the more valuable grasses as it now does of weeds, sedges, and rushes. As many of the meadows along Sand Creek have been irrigated in the manner described for a number of years and as the vegetation is of the moisture-loving variety, a scarcity of water such as that experienced during the past season results in a greatly diminished yield of hay.

DITCHES.

Undoubtedly much of the difficulty experienced in the distribution and economical use of water in districts similar to the one under consideration results from the fact that each ranchman owns and controls his own ditch system. Several ditches are often built upon one ranch, each irrigating from 50 to 300 acres. The total length of ditches in the whole Sand Creek district amounts to only 32.5 miles, being no more than a system of laterals under some large canal. Yet each ditch, however small, has its own separate priority, and its control must be subject to the same State supervision as would a large canal. The same problems of water administration are therefore encountered upon Sand Creek as would be met with upon a stream of ten times its size and importance.

The system of small separate ditches results in the double disadvantages of limiting the area capable of irrigation and a low duty of water. Through most of its length in Wyoming Sand Creek has an unusually slight fall; so that in order to irrigate relatively small areas a long length of ditch is required. As ditch construction is expensive, the area which a ranchman is able to reclaim by his own efforts is necessarily small. A line of main canal or ditch on either side of the valley, diverting water from the creek near the point where it empties into the valley, besides commanding the land now watered, would make it possible to irrigate a much larger area. Built on the cooperative plan, as in other portions of the West, and under cooperative management, such a system would also allow of greater economy in the use of water through distribution in rotation. Such a project, although favored by a few ranchmen who see its advantages, is opposed by the majority, who are disinclined to abandon their present ditches and water rights and who fear the advantages to be gained will not be commensurate with the expense of such an undertaking. In the near future, however, it is probable that some more effective means of distribution, together with storage of the remaining water supply, must be resorted to. The ditches in the Wyoming portion of the district are worthy of but very brief mention. The largest, the Lone Tree Ditch, is but 10 feet wide and 2 feet deep. The grades of the various ditches are from 4 to 10 feet per mile. No irrigation structures of interest or importance are found. A few of the ditches have no headgates, little or no regulation being made. No measuring weirs or flumes are found in the district.

SEEPAGE.

Seepage undoubtedly has much to do with the duty of water and with the distribution of water from the stream. The soil being of a porous character, it is to be expected that the seepage gains and losses will be large, and this is what was found by a series of measurements made the past season.

The diagram (fig. 3, p. 110) shows graphically the total flow of the different ditches previously mentioned, as well as the flow of Sand Creek at the upper and lower gaging stations, from the 25th of April, at which time irrigation started, to the end of July. This diagram shows that on several dates the amount of water used by the different ditches exceeded by several acre-feet that passing the upper gaging station, while at the same time a small amount was flowing at the lower gaging station. It has been explained that the soil is very porous and that much of the land irrigated is in the stream bottoms or upon the hillsides immediately adjacent to the creek. Much of the water applied to the land probably returns to the stream and becomes immediately available for the use of ditches diverting water lower down. To determine to what extent this occurs measurements were made of the flow of Sand Creek just above and just below the meadow of Mr. Hardman. We have elsewhere stated that the use of water upon this meadow more nearly represented the ordinary use than did any other upon the stream during the past season. It must be expected, therefore, that such results as were obtained from the seepage measurements would likewise be representative.

The results are shown in the following table:

Seepage measurements on Sand Creek.

Flow in creek.			Amount being applied to meadow.	Per cent of amount applied returning
Above meadow.	Below meadow.	Difference.		
Cub. ft. per sec.	*Cub. ft. per sec.*	*Cub. ft. per sec.*	*Cub. ft. per sec.*	
6.11	6.60	0.49	3.4	7.6
.39	2.04	1.65	1.6	95.1
.70	.72	.02	.0	....

The first set of these measurements was made soon after water was turned on the meadow, and it is probable that the ground had not become sufficiently saturated to cause much seepage. The second set was made some time after water had been turned on and shows a large increase in the ratio of seepage to the amount of water applied. The third set was made when the meadow was dry, and consequently there was only a very slight difference between the two measurements.

In addition to the above, three series of measurements were made to determine the effect of seepage upon the stream flow in a certain length through the valley. In the section selected, which was about 18 miles in length, no visible inflow from tributary streams occurred during the progress of the respective measurements. The results are shown in fig. 4. This diagram shows the net gain or loss between the respective points of measurement. All diversions have been subtracted.

The first measurements of the series were made on May 25. At this

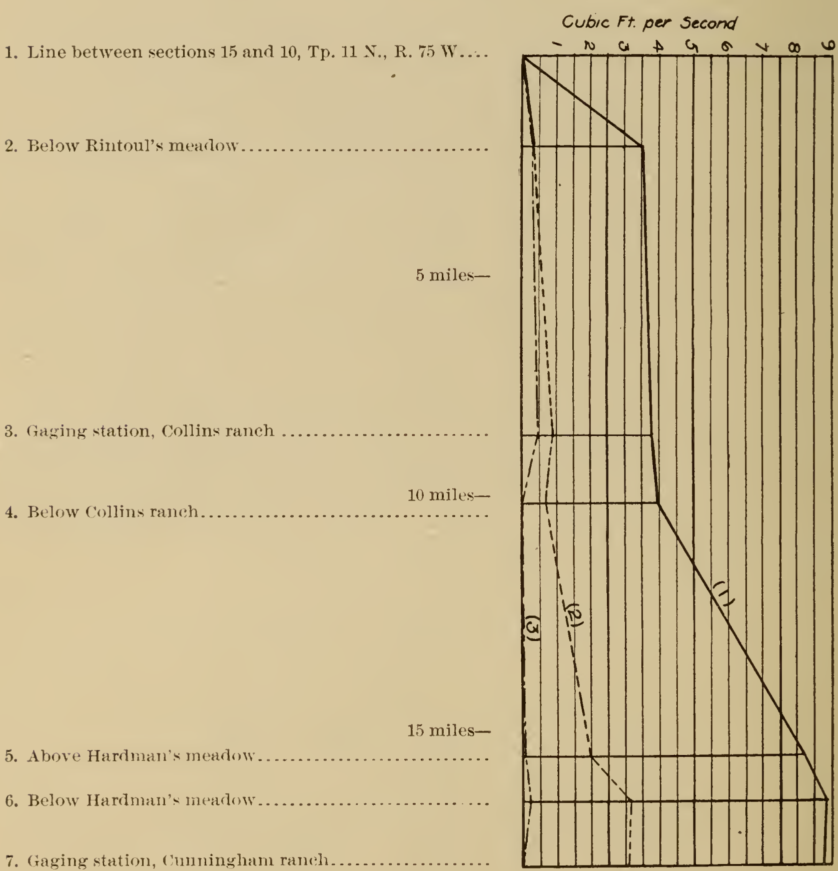


FIG. 4.—Diagram showing seepage gains and losses in flow of Sand Creek.

time water was being used very generally throughout the valley in large quantities and the seepage, as shown by the diagram, is correspondingly large. The second set, being taken in the season when water was not so abundant, shows a corresponding decrease in the seepage, and the last, taken when but little water was being used, indicates that very little water was returning to the stream. Between the three measurements there seems to be a very satisfactory correspondence, so that the results are probably accurate.

The above considerations seem to show quite conclusively that were it not for the fact that a great deal of the water used returns to the stream the area which could be irrigated would be much smaller. As we have elsewhere stated, no data is available as to the flow of the stream in normal seasons. From the high-water marks and from the testimony of the residents of the district as to the levels attained by the stream in flood time we are, however, able to estimate that the flood discharge is probably between 75 and 100 cubic feet per second. Upon the legal basis of 70 acres per second-foot (which we have reason to believe is too high a duty for this district) the total area capable of being irrigated in flood time would be only about 6,000 acres. The actual area under ditches is about 5,000 acres, from which it is seen that the flow of some of the lower ditches in dry or even in normal years must be made up almost entirely of seepage water.

THE INTERSTATE WATER-RIGHT PROBLEM.

The legal phase of the irrigation problem in this district is of unusual interest and importance. It involves the question of interstate rights, a question which is very intimately connected with future irrigation development on many of the larger streams of the West.

As may be seen from the accompanying map (Pl. VI), Sand Creek rises in Colorado and about half of its course lies in that State. Nearly all of the irrigated land, however, lies in Wyoming. Much of this land has been under irrigation since 1878, and a smaller portion since about 1870.

Nearly all of the land lying in Colorado watered from Sand Creek has been under irrigation for probably not over ten years, though a small portion has been watered for perhaps twenty years. The irrigation of this land has never very seriously interfered with the use of water by the Sand Creek appropriators in Wyoming. The land irrigated has a steep slope toward the stream, and the return seepage is large, as shown by the diagram (fig. 4, p. 114), in which the seepage gains from these lands are shown between points 1 and 3. Although the use of water by the Colorado appropriators might diminish the present flow of the stream, the ultimate result would be that the drainage from these lands would tend to sustain the flow later in the season, probably, however, too late to be of material aid in irrigation. This influence of seepage has been recognized by the Sand Creek ranchmen, and consequently no complaint has been raised previous to this time against the use of the waters of the stream by these Colorado appropriators, although their rights are inferior in time to those of many of the ranchmen along Sand Creek in Wyoming.

In May of 1902, however, a canal was completed high up on a stream in Colorado by which it was made possible to divert the entire

flow of Sand Creek at the point of diversion and empty it into Sheep Creek, a tributary of the Cache la Poudre River, an important Colorado stream lying in the drainage basin of the South Platte River. (Pl. VII.) The water diverted from Sand Creek is subsequently diverted from the Cache la Poudre River and stored in a reservoir from which it is afterwards drawn to irrigate beet lands in the vicinity of Fort Collins. The ditch thus connecting the two watersheds is called the Divide Ditch. Although this year the flow of Sand Creek alone has been utilized, the works have now been completed by which during the coming season the headwaters of a number of streams tributary to the Laramie River will be diverted into the Sand Creek watershed and then with Sand Creek water emptied into the watershed of the Cache la Poudre. The chain of ditches by which this unique scheme is carried out is shown on the accompanying map. (Pl. VI, p. 100.) As will be seen by the map, the whole system lies in Colorado. The water is both diverted and used in that State.

It is of course evident that this diversion of water from one watershed to another brings about a number of complications of a legal nature. The Sand Creek water and also that flowing into the Laramie River by other channels has already been appropriated and put to beneficial use by both Wyoming and Colorado citizens whose ranches are situated upon the streams in question below the respective points of diversion of the ditches mentioned. While the Colorado appropriators whose interests are thus affected have redress in the courts of their own State, the Wyoming citizens have no means of maintaining their rights except by an appeal to the United States courts. Such an appeal has been made by the Sand Creek landholders whose interests are affected. The following is extracted from the bill of complaint filed by their counsel:

In 1867 and the succeeding years and long prior to the acts of the defendants hereinafter complained of the plaintiffs and their respective grantors began to cultivate their said lands and to produce and harvest crops of grass and hay and other crops thereupon, originally by natural irrigation from the waters of Sand Creek, and later by artificial diversions by means of dams, ditches, flumes, and other works made for the purpose of extending and improving the irrigation of such lands and by such and other means of diversion and by the application of the waters of said creek to the soil, and through the cultivation thereof the plaintiffs and their respective grantors made appropriations and acquired rights prior in time to those of the defendants to the use of all of the waters of Sand Creek, which appropriations and rights they have maintained up to the present time, and of which they are now in possession and enjoyment except as interrupted by the wrongful acts of the defendants, hereinafter complained of.

Adjacent to the irrigated lands of the plaintiffs are large areas of arid pastoral lands both in public and private ownership, upon which the cattle of the plaintiffs and their grantors have been accustomed to range and graze from 1867, being dependent for the use of such pasturage upon the access to the running waters of said creek, without which the pastoral lands aforesaid would be largely inaccessible and useless.

From 1867 the plaintiffs and their grantors have been accustomed to draw their

FIG. 1.—HEAD GATE AND DAM OF DIVIDE DITCH.

FIG. 2.—VIEW OF DIVIDE DITCH, SHOWING LOSS BY SEEPAGE.

water supply for domestic purposes from said creek, and the plaintiffs are now largely dependent upon such source of supply.

The defendants, on or about May 1, 1902, and at divers times from that date to the filing of this bill, have, by means of dams and ditches and otherwise, wrongfully and unlawfully obstructed and diverted the flow of the waters of said creek and its tributaries and drainage basin, the common source of supply, and intercepted the melting snows and the floods and rains of said drainage basin and led them away from the channel and in some instances from the drainage basin of said creek and wasted and applied them to other uses, thereby cutting off the flow of the said stream into Wyoming and to the plaintiffs' ditches and lands and depriving the plaintiffs of all use of said waters; and the defendants still repeat and continue and threaten to further and permanently repeat and continue their said wrongful and unlawful acts to the permanent injury and deprivation of the plaintiffs' source of supply, and, unless restrained by the order of this court, the defendants will thus further and permanently injure and deprive the plaintiffs of their said source of supply.

The diversions and applications of water by the plaintiffs, as aforesaid, are wholly within the State of Wyoming, and the diversions and applications of water aforesaid by the defendants are wholly within the State of Colorado.

The plaintiffs are informed and verily believe that the defendants claim and pretend, by reason of the interstate character of said stream and by reason of the diversity of citizenship and the location of lands of the plaintiffs and those of the defendants in different States, that the defendants have the right to wholly exclude the plaintiffs from the use of the waters of said creek and to take and apply and appropriate, in Colorado, all of the waters of said creek in disregard and exclusion of the vested and acquired prior rights of the plaintiffs aforesaid, and the defendants deny and dispute all rights of the plaintiffs to make any appropriation or use of the waters of said creek without the limits of Colorado, and claim all of the said waters as lands granted by the constitution and laws of Colorado exclusively to the citizens and occupants of lands in said State.

The plaintiffs have no other practicable or available supply of water, and the aforesaid obstructions and diversions by the defendants of the waters of said creek have deprived and now deprive and will, if repeated or continued, further deprive the plaintiffs of the necessary supply of water for their cattle and for the irrigation of their lands and for domestic uses, and have greatly reduced the growth of crops and will, if repeated or continued, cause the plaintiffs' irrigated lands to deteriorate and relapse into a state of aridity and barrenness which will wholly or largely destroy their value and thus deprive the plaintiffs of their property, and will, if further repeated or continued, render the pastoral lands aforesaid, both of public and private ownership, inaccessible and useless for grazing purposes.

The complaint asks to have the defendants cited to show what rights they claim and also to have them restrained from future diversion of water.

It is, of course, outside of the province of this report to discuss the respective rights of the parties to this suit. That the Wyoming ranchmen have just grounds of complaint can not, however, be denied. Although they have been settled upon the stream a sufficient length of time to acquire rights which would hold against parties diverting water above them were the stream entirely within their own State, in this case they suddenly find themselves deprived of a large portion of the waters of the stream upon which their prosperity almost entirely depends, and they have no means of redress except by an appeal to the Federal courts. The damage sustained by them through the diversion of the waters of the stream is difficult of determination. From

the data at hand it is, however, comparatively easy to arrive at an approximation to the truth.

As the Divide Ditch alone was completed during the past season no water was diverted from the other streams flowing into the Laramie River. As we have stated elsewhere, the shortage of water during the past season was due not only to this diversion of Sand Creek water by Colorado parties, but also to an unusually dry season. From January 1 to June 28 there was little or no rainfall, and, to make matters worse, there was only a very slight amount of snow stored in the mountains and it was almost entirely melted by the end of May. The precipitation from October 1, 1901, at which time the investigation was started, up to October 1, 1902, is given in the following table, as well as an average for the same period during a previous ten years.

Rainfall at Laramie, Wyo., from October, 1901, to September, 1902, inclusive.

Month.	1901-1902.	Average previous ten years.[a]	Month.	1901-1902.	Average previous ten years.[a]
1901.	*Inches.*	*Inches.*	1902—Continued.	*Inches.*	*Inches.*
October	1.28	0.83	May	.26	1.74
November	.00	.27	June (12, 0.03; 28, 0.49; 29, 0.08)	.60	1.20
December	.21	.36	July	1.49	1.47
1902.			August	.40	1.06
January	Trace.	.27	September	1.58	.67
February	.26	.34			
March	.41	.97	Total	7.29	10.49
April	.80	1.31			

[a] Excluding 1901, for which records are incomplete.

From this table it is seen that the rainfall during the period under consideration has been about three-fourths the mean of the previous ten years. It is seen further that from March to July, 1902, a period during which rain is much needed, both for irrigation and for the ranges, that there was only 1.66 inches of rainfall against a normal of 4.25 inches during the previous years, and that of this 1.66 inches 0.57 inch fell on June 28 and 29, too late to do much good to the hay meadows.

These figures are from the records of the meteorological department of the University of Wyoming, which is near enough the district under discussion to make the data probably very nearly correct for that locality.

The relative effect of the two causes mentioned on the shortage of water this season can not be stated with any exactness. The water diverted by the Divide Ditch is, of course, lost to the users of water farther downstream. As it is carried to another watershed only the small amount lost in transit prior to the ditch reaching the other watershed can return to the stream by seepage. The flow of Sand Creek was undoubtedly affected also by the reduced flow, due to shortage in

precipitation of several large feeders entering the stream below the head of Divide Ditch.

The variation in the discharge at the upper gaging station when the head gates of the ditch were opened or closed give some idea of the influence exerted upon the flow of Sand Creek by the use of Divide Ditch. On May 9 the water was turned into the Divide Ditch for the first time. On May 11 the discharge at the upper rating flume on the creek was 59 acre-feet per day. On May 12 the discharge fell to 38 acre-feet per day.

In the following table is given a record of the flow of the Divide Ditch from May 9 to July 1, 1902. These figures were obtained by the daily gage readings at the lower end of the ditch just before it discharges into Sheep Creek. From May 9 to June 10, inclusive, measurements were made by means of a rectangular weir of rather imperfect construction. On June 10 a rating flume was installed, in which the measurements were afterwards made.

Flow of Divide Ditch.

Day.	May.		June.		July.	
	Average discharge in cubic feet per second.	Discharge in acre-feet per day.	Average discharge in cubic feet per second.	Discharge in acre-feet per day.	Average discharge in cubic feet per second.	Discharge in acre-feet per day.
1			22.30	44.16	1.70	3.87
2			19.20	37.91	1.90	3.76
3			15.00	29.70	1.20	2.38
4			14.40	28.62	1.20	2.38
5			14.40	28.40	.97	1.93
6			13.40	26.54	.48	.94
7			13.40	26.54	.20	.40
8			11.90	23.57	.20	.40
9	7.80	15.44	9.90	19.71	.32	.65
10	12.80	25.45	7.67	15.19	.20	.40
11	16.60	32.88	6.75	13.36	.00	.00
12	18.30	36.29	5.62	11.13	.00	.00
13	30.70	60.89	4.49	8.90	.00	.00
14	25.30	50.08	5.62	11.13	.00	.00
15	35.80	70.89	4.49	8.90	.00	.00
16	30.70	60.89	4.49	8.90	.60	1.19
17	31.30	62.07	3.31	6.54	.75	1.48
18	25.80	51.18	2.21	4.36	.75	1.48
19	22.20	44.05	2.21	4.36	.45	.90
20	18.90	37.42	2.21	4.36	.32	.65
21	16.60	32.87	2.21	4.36	.20	.40
22	17.70	35.15	2.21	4.36	.15	.30
23	16.90	33.46	1.59	3.16	.00	.00
24	16.10	31.98	1.59	3.16	.00	.00
25	16.10	31.98	1.20	2.38	.00	.00
26	20.00	39.70	1.20	2.38	.00	.00
27	24.10	46.72	1.20	2.38	.00	00
28	22.30	44.16	1.20	2.38	.00	.00
29	23.50	46.53	2.20	4.36	.00	.00
30	22.30	44.16	1.59	3.16	.00	.00
31	21.10	41.88			.00	.00
Total		976.12		394.36		23.01

As shown by the table, a total of 1,393.49 acre-feet of water was diverted from Sand Creek and emptied into Cache la Poudre watershed in 1902. This amounts to about 60,700,000 cubic feet. The value of this water as sold in Colorado is $100 per 1,000,000 cubic

feet, which would mean that the water thus diverted was worth \$6,070 to the owners of the Divide Ditch. This water would have had much less value as used in Wyoming. As shown on page 110 the average value of an acre-foot of water used in the Sand Creek district is not far from \$1, figured from the yield per acre in hay. On this basis the Wyoming appropriators sustained a loss of \$1,393.49. This is not, however, the only loss. It is not only the damage resulting from the shortage in the hay crop that must be considered, but also the permanent depreciation in the value of the land resulting from the lack of water for its irrigation. Land under irrigation is valued by the Sand Creek ranchmen at from \$10 to \$25 per acre. The average value as placed by them is \$15 per acre. Land without water they value at about \$2 per acre; fencing they value at \$50 per mile, which would make the value of an acre in a fenced but unirrigated section about \$2.30. Thus there would be a depreciation of \$12.70 per acre in the value of land should the water supply be entirely cut off. We have elsewhere explained that it was quite impossible to make any determination of the actual area to which water was applied because of the unequal and uneven manner in which the land was irrigated. Water was let into all of the ditches ordinarily used, so that under none of them could it be said that absolutely no water was applied to the land. It is therefore utterly impossible to determine just how much land was without water during the past season. The only way in which it is possible to make even an estimate is to assume that the entire area under ditches could have been irrigated had the water diverted by the Divide Ditch been available for the use of the Sand Creek ranchmen. By a proportion between the amount of water actually available, that which would have been available had the Divide Ditch not been built, and the total area under ditches in the Wyoming portion of the district we may arrive at some approximation to the truth. The total area under ditches is about 5,000 acres. The amount of water which entered the upper portion of the valley from the 1st of April to the last of June, at which time irrigation may be considered to have ended, was 1,735.99 acre-feet. The amount of water diverted by the Divide Ditch during the same period was 1,370.48 acre-feet. The total amount of water which would have been available, therefore, was 3,106.47 acre-feet. By proportion, the amount of land which probably was irrigated the past season is found to be 2,794 acres. This means that 2,206 acres were without water. If the past season be taken as typical and the decrease in the water supply as permanent, then, on a basis of depreciation of \$12.70, there was a loss of \$28,016.20.

Combining the permanent depreciation of \$28,016.20 in the value of land that was deprived of water with the loss for the season of \$1,393.49, the value of the 1,393.49 acre-feet diverted, it is seen that

the total loss caused by the Divide Ditch diversion estimated at the close of the season of 1902 was $29,409.69. This loss is surprising when it is considered that it occurred in a district where the total assessed valuation of real estate and improvements is only $112,000.

RANGE PROBLEMS.

On Sand Creek, as indeed nearly everywhere throughout the State of Wyoming at the present time, the question of the use and control of the grazing lands adjacent to the stream is of the greatest complexity and importance and the situation is one demanding the early attention of our legislative bodies.

It is unnecessary to dwell at much length upon the present condition of the ranges or the causes by which the present situation has been brought about, as the facts are widely known. In this district, as elsewhere, the entire difficulty may be said to have originated in the short-sighted endeavor of the early stockmen to make the most of the "free grass" while it lasted, regardless of consequences. During the "boom times" of the cattle business, from 1871 to 1885, stockmen invested in immense herds of cattle, which were allowed to roam at large and which were more in numbers than the range could support without injury. Because of the presence of water easily available for stock the Sand Creek country suffered probably as much injury as any from the excessive trampling and close cropping of the pasturage by the great herds of the speculative stockmen. From this early impoverishment the range has never fully recovered, although after the decline of the range stock industry in the latter half of the eighties the number of cattle occupying the ranges was greatly reduced. According to the testimony of ranchmen who have been in the district since its first settlement, many areas which now have only sparse and scattered growth of vegetation, consisting mostly of cactus, formerly had comparatively thick covering of grass, which, in favorable seasons, grew to the height of a man's knee. The difference between former and present conditions can probably best be realized when it is learned that on areas which formerly could support from 50 to 100 animals per square mile without crowding there is now barely feed enough for 20, or at best 30. Sheep have never been grazed very extensively in this district, so that such damage as has been done is very largely that due to overstocking by cattle. This exhaustion of the natural pasturage, together with the wholesale fencing and use of the remaining public lands by the large cattle owners, has left the ranchmen of moderate means in serious straits for the summer and winter pasturage of their cattle. On some ranches enough hay is grown to feed during the winter many times the number of cattle which can be supported by grazing on the adjacent ranges during the summer.

It is probable that in this locality the range might be restored to its

former condition by artificial seeding and a simple course of cultivation. The most practicable way, however, seems to be to let conditions correct themselves naturally, allowing the few remaining grasses to reseed the denuded areas and protecting the new growth by a careful and conservative system of pasturing. This remedy is evident to most ranchmen, and explains the efforts which now and for some time past they have been making to acquire inclosed tracts of grazing lands. From these tracts they are enabled to exclude the cattle of their neighbors, and in them they pasture their own cattle in a way which will be most likely to induce a rapid and permanent improvement in the pasturage. This separate control of grazing areas also allows the improvement of the herds by the use of pure-bred stock, something which would be impossible under the old open-range system.

Ranchmen favor the enactment of some law by which they could lawfully acquire areas of grazing land over which they could exercise control for a term of years sufficiently long to justify them in using such means as are effective in reestablishing the growth of the native grasses. Realizing the great importance of safeguarding the interests of the small stockmen, they believe it to be necessary to prevent the possibility of the large cattle companies gaining a monopoly over large areas of grazing lands. Such an end would, in the opinion of many, be attained by making the area of grazing land obtainable bear a certain proportion to the area of irrigated land; for example, 1 acre of irrigated land should entitle the landowner to 5 acres of grazing land. However, the problem is one of many complexities, and to solve it in a way which shall be satisfactory to all the various interests concerned will be a task of much difficulty.

CONCLUSIONS.

Although many results of the investigations of the past season can not be taken as representative of normal conditions, still it is thought that the following conclusions can safely be drawn:

(1) That in the irrigation of native hay a wasteful and extravagant use is made of water which might be used to better advantage if less were applied, or which, if used in the irrigation of some forage crop such as alfalfa, would give a much larger yield for the same amount of water judiciously applied.

(2) That native hay is probably, however, the only crop which could be grown with profit without storage of the water supply. The period of greatest use in the irrigation of native hay is the period of maximum supply, and the supply becomes exhausted at a time when crops other than native hay most need the water.

(3) That the system of numerous small ditches, besides restricting the area capable of irrigation, produces unnecessary complications in water distribution and favors a low duty of water.

(4) That seepage has a surprising influence in keeping up the flow of ditches whose head gates may be separated by only a few miles of irrigated land.

(5) That by diversion of the headwaters of Sand Creek into another watershed Wyoming irrigators will be deprived of a large portion of the late spring flow of the stream, which comes mainly from the meltings of snow accumulated in the higher valleys of the mountains and is therefore all the more valuable for irrigation.

(6) That conditions of which we have an instance in the Sand Creek district demand immediately some judicial or legislative action defining the respective rights of parties irrigating from the same stream but separated by a State boundary.

(7) That the present depleted condition of the natural pasturage and the trend of the cattle industry toward improved breeds of cattle have rendered obligatory the abolishment of the open range in this district.

(8) That as the area of the homestead and desert land claims are inadequate to support a profitable number of cattle, the adjacent areas of public land should be rendered available by leasing, or some other means, for exclusive use and control by resident landowners, with certain restrictions as to the amount and location of land available.

IRRIGATION IN WASHINGTON.

By O. L. Waller.

SUNNYSIDE DISTRICT.

Measurements of the quantity of water supplied by the Sunnyside Canal and the areas irrigated with this water have been made for several years past, and the measurements for 1900 and 1901 have been given in former reports.[a] Since this report is a continuation of these reports, no general description of the canal system is given here.

The following tables show the water passing the head gates of the Sunnyside Canal for the season of 1902, the area of the different crops irrigated, and the rainfall at Sunnyside:

Total monthly discharge of Sunnyside Canal for 1902.

Month.	Acre-feet.	Month.	Acre-feet.
April	9,981.5	August	40,244.2
May	18,495.2	September	29,877.8
June	27,410.5	October	16,921.1
July	29,014.0		

Rainfall at Sunnyside, 1902.

Month.	Inches.	Feet.	Month.	Inches.	Feet.
January	0.64	0.053	August	0.00	0.000
February	1.91	.159	September	.27	.023
March	.17	.014	October	.72	.060
April	1.54	.128	November	1.11	.092
May	.86	.072	December	1.18	.098
June	.11	.009			
July	.15	.013	Total	8.66	.721

Rainfall at Sunnyside, 1896–1902.

Year.	Inches.	Year.	Inches.
1896	8.05	1900 to (November 1)	4.85
1897	8.10	1901	([b])
1898	3.03	1902	8.66
1899	7.72		

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 104 and 119.
[b] Not known.

Acreage under cultivation, season 1902.

Crop.	Acres.	Crop.	Acres.
Alfalfa	10,159.50	Hops	310.50
Timothy and clover	3,234.50	Miscellaneous	1,577.50
Orchard	2,481.70		
Potatoes	926.25	Total	18,870.70
Corn	180.75		

Duty of water under the Sunnyside Canal, 1902.

[Area irrigated, 18,870.7 acres.]

Month.	Water used.	Depth of water.	Rainfall.	Total depth of water received by land.
	Acre-feet.	*Feet.*	*Foot.*	*Feet.*
April	9,981.5	0.53	0.128	0.66
May	18,495.2	.98	.072	1.05
June	27,410.5	1.45	.009	1.46
July	29,014.0	1.54	.013	1.55
August	40,244.2	2.13	.000	2.13
September	29,877.8	1.58	.023	1.60
October	16,921.1	.90	.060	.96
Total	171,944.3	9.11	.305	9.41

The season of 1902 shows a very large amount of water passing the head gates for the acreage under cultivation. Presumably the seepage loss is considerable, but as no determinations for seepage were made this season the amount of it can not be estimated. It is quite likely that, with the weirs now being set at the headings of all laterals, some very satisfactory data may be collected next season.

Comparison of water used under the Sunnyside Canal, by seasons.

Year.	April.	May.	June.	July.	August.	September.	October.	Totals.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1898	5,587.44	8,762.97	10,690.91	15,187.44	18,253.88	10,894.54	8,957.50	78,334.69
1899	6,000.00	11,884.96	13,654.21	15,548.35	19,385.26	13,840.66	10,058.93	90,372.37
1900	10,788.10	14,389.73	16,109.75	21,814.21	22,552.17	15,387.77	11,012.56	112,054.29
1901	7,184.30	18,520.80	20,692.00	29,002.00	33,120.00	19,133.00	16,306.10	145,958.10
1902	9,981.50	18,495.20	27,410.50	29,014.00	40,244.20	29,877.80	16,921.10	171,944.30

Duty of water under the Sunnyside Canal, 1898–1902.

Year.	Area irrigated.	Water used.	Depth of water used in irrigation.	Rainfall, April 1 to October 31.	Total depth of water received by land.
	Acres.	*Acre-feet.*	*Feet.*	*Foot.*	*Feet.*
1898	6,883.00	78,334.69	11.38	0.16	11.54
1899	8,497.00	90,372.37	10.64	.22	10.86
1900	10,947.00	112,054.29	10.24	.28	10.52
1901	14,964.00	145,958.10	9.75	.16	9.91
1902	18,870.70	171,944.30	9.11	.31	9.42

DUTY OF WATER AT SUNNYSIDE STATION.

The Sunnyside station was established to determine the actual duty of water as applied by conservative farmers. The group of farmers interested volunteered to undertake the test. They were advised to use all the water they needed, but to waste as little as possible. The record was taken once a day by Patrolman C. M. Mudd. On account of large quantities of silt in the water the lower contraction on the weir was not perfect; consequently there is an element of error in the results. However, they establish the fact that 8 feet or more of water, the depth shown by the preceding tables, is not necessary to raise a crop in the Yakima Valley. The following table shows the water used at this station:

Table showing water received by land at Sunnyside station.

[Area irrigated, 80 acres.]

Month.	Water used.	Depth of water.	Rainfall.	Total depth of water received by land.
	Acre-feet.	*Feet.*	*Foot.*	*Feet.*
April	0.00	0.00	0.13	0.13
May	9.84	.12	.07	.19
June	26.77	.35	.01	.36
July	51.57	.64	.01	.65
August	54.95	.69	.00	.69
September	50.72	.63	.02	.65
October	24.63	.30	.06	.36
Total	218.48	2.73	.30	3.03

Of the 80 acres irrigated 54 acres yielded 452 tons of alfalfa, and from the 26 acres of orchard 2,200 boxes of apples, 210 boxes of pears, and 10 tons of prunes were gathered.

DUTY OF WATER ON THE HOPYARD OF R. D. DUNN.

This entire yard consists of 38 acres of old stock and 12 acres of new. The entire crop is reported as injured by the use of too much water, followed by rain and damp weather. These conditions favored the lice. The cold water, only three days from the snow fields, chilled the ground and retarded the growth. The vines presented a yellow appearance; water grass became very abundant and the ground baked. The old yard yielded 27,800 pounds of hops, or 732 pounds per acre, or less than half that reported for 1901; the young yard yielded not more than 2,100 pounds.

In 1901, 20 acres of this yard were subsoiled. As reported for that year, the crop on that part of the yard was short. This season's crop also shows the same result, which was probably the result of the heavy root pruning.

The following tables show the duty of water on this hopyard:

Water used on Dunn's hopyard.

Day.	May.	June.	July.	August.	Day.	May.	June.	July.	August.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*		*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	1.650	1.575	....	18	....	0.118	1.152	....
2	....	1.625	1.575	1.088	19	....	.244	1.308	....
3	....	1.687	1.575	1.742	20	....	.228	1.567	....
4	....	1.750	1.575	1.742	21	....	.105	1.635	....
5	....	1.750	1.626	1.780	22	....	....	1.815	....
6	....	1.687	1.626	1.825	23	0.938	.595	1.742	....
7	....	1.687	1.690	1.604	24	....	1.209	1.815	....
8	....	1.410	1.626	1.190	25	1.510	1.267	1.742	....
9	....	1.508	1.690	1.266	26	1.510	1.209	.378	....
10	....	1.528	1.626	1.502	27	1.510	1.267	....	....
11	....	1.565	1.537	1.514	28	1.510	1.494	....	....
12	....	1.502	1.408	1.519	29	1.510	1.745	....	....
13	....	1.367	.969	1.444	30	1.510	1.625	....	....
14	1.208	1.127	.942	.481	31	1.510	....	....	....
15	1.208	....	.848	....					
16	1.208	....	1.021	....	Total	16.340	32.949	36.803	18.697
17	1.208	....	.740	....					

Duty of water on Dunn's hopyard.

[Area irrigated, 50 acres.]

Month.	Water used.	Depth of water.	Rainfall.	Total depth of water received by land.
	Acre-ft.	*Feet.*	*Foot.*	*Feet.*
April	00.00	....	0.13	0.13
May	16.34	0.33	.07	.40
June	32.95	.66	.01	.67
July	36.80	.74	.01	.75
August	18.70	.37	.00	.37
September	00.00	0.00	0.02	0.02
October	.00	.00	.06	.06
Total	104.79	2.10	.30	2.40

VALUE OF CROPS ON DUNN'S HOPYARD.

The market price of hops was 26 cents per pound. At that rate the crop on the old yard would be worth $7,228, and on the young yard $176, making a total of $7,404, or $148 per acre.

VALLEY VIEW DAIRY FARM.

This farm, owned by Mr. R. D. Young, is located on a knoll and is supplied by a pipe line, carrying 0.94 cubic foot per second of water when in perfect working order. Barring any accident to the main canal, this flow is constant and is all used on 40 acres. Mr. Young has made a study of its application in order to get the best service from the supply furnished. The following crop report is submitted by him for 1902:

There are in my place 40 acres, divided as follows: Twenty acres of orchard, 16 acres of alfalfa, 2 acres of clover, and 2 acres of lawn. Among the trees in the orchard there are 100 grapevines and one-fourth acre of blackberries. The orchard is not yet in full bearing. This year's crop was taken from 200 apple trees, 188 pear trees,

and 389 prune trees. The crop consisted of 1,020 boxes of apples, 200 boxes of pears, 394 boxes of prunes, 1 ton of grapes, 50 crates of blackberries, 112 tons of alfalfa, and 4 tons of clover.

Alfalfa was cut four times and irrigated four times; clover was cut twice and irrigated three times. The orchard, with the exception of that part planted with the small fruit, was irrigated three times; the small fruit, several times.

OVERIRRIGATION.

J. L. Stackhouse, engineer for the Washington Irrigation Company, which operates the Sunnyside Canal, has furnished the following statement of the effects of overirrigation and suggests some practical remedies:

In this district with about 7 or 8 inches natural precipitation, of which none is lost by run off, we add, according to the published records of the district, from 100 to 132 inches of irrigation water. An undetermined proportion of this is lost as waste and evaporation.

Evaporation is probably greater here than in a moister climate; how much greater is only a conjecture. We still have four or five times as much available moisture as has the rainfall region. The question is, do we really use as much as that in growing our crops, or is a large portion of it allowed to soak away into the ground beyond the reach of plant life? The conditions noted indicate that the latter suggestion is correct. The writer has frequently, during the past season, measured ditches where 1 cubic foot per second of water was being run on 10 acres or less for days at a time, and is satisfied that cases are numerous in which overirrigation has been carried on, to the injury of the land, the crops, and everybody interested. Air is as necessary to the roots of plants as water, and where so much water is applied the air is excluded, thus shortening the crop and water-logging the ground.

The value of the property as well as the health of the community is threatened and a hardship is worked on the irrigation company by the use of such excessive amounts of water. The carrying capacity of the distributing system is also taxed to the point of danger.

These are not imaginary evils, as every one who is acquainted with the situation knows, and now a suggestion as to their correction.

The first point that observation brings out as a means of reducing the amount of water used is the preparation of the land. This should be made even enough to prevent backing up and overflowing irrigation rows, for where this happens the water spreads out, the lower end of the row gets no water, and the water running into pools is worse than wasted, because it hardens the soil and soaks down to raise the underground water level. Another adverse condition noted, and a most common error in the Sunnyside district, is the excessive length of the irrigation furrows. It is acknowledged by those who are best able to judge that an irrigation can be completed in much less time and with much less water in short rows than in long ones. On level ground 20 to 30 rods ought to be the common length and 40 rods the limit. In long rows the upper end becomes supersaturated before the water gets to the lower end, involving injury to the crops and waste of water. Long rows doubtless look well in the field and are convenient in handling hay crops, but it is the belief of the writer that they are in a great measure responsible for the conditions before mentioned, and in irrigation districts where water is scarce they are not used. Formerly it was the custom to make the distance between the rows 3 feet or more. It is now demonstrated by practical men that for seeding grass on new ground 16 to 20 inches is better, as the ground is moistened more quickly and with less water. Another point worthy of mention is the attention a field requires while the water is on. It

is a common practice to turn on the water, regulate the flow in the furrows, and then go to other work, perhaps not seeing the field again for hours. The consequence is that while many of the rows will be all right there will be some that will be obstructed or without a sufficient head of water and will not be wet when the others are ready to have the water turned off, so water must run on the whole section for another day in order that these neglected patches may be wet. The result is that much of the field is overirrigated and the water is added to the overflow or run-off through the waste ditch. The remedy, of course, is to stay by the field while the water is on and see that it is properly distributed to all parts in the least possible time. In years past, when the acreage of irrigated land was not so large and the water supply was ample, these objectionable features were not so apparent, but now the time is near when they must be avoided or evils will result.

There is one other suggestion worthy of mention: That is that if the farmers on a lateral take turns in using the water, so that each may have a larger head of water, he need not use it so long. A company having determined the area to be watered by each lateral could turn into it the proportion of water to which it is entitled. The farmers could arrange before the beginning of the season the order and time in which each should have the use of the water, and then all plan their work to that end. The advantage gained would be that each man, having a much larger head of water, could get over this ground with less waste of time and water. There would be a comparatively even flow of water in the ditch, thus increasing the security by avoiding the danger of overflowing and breaking ditches incurred when enough water is turned into the ditch for all to use water at the same time. No one on a small place can irrigate in a satisfactory manner with only the small stream he is entitled to running all the time, but with four or five times as much water running only one-fourth or one-fifth of the time he can irrigate well and have time for other work. This being true, we must either rotate in the use of the water as suggested or else continue this straining of ditches to carry enough water that all may have a good working head. This system might not work well where part of the users of water out of a lateral were seeding new ground; but, with this exception, I see no reason why it should not be successful, and in the instances in which it has been tried the people say they get better results with half the water used in the ordinary way.

Mr. J. S. Harrison says:

The overirrigation complained of is principally the result of running water too great lengths in the irrigating furrows, especially during the process of seeding. In our light soil it is necessary to keep the land wet from the time of seeding until the plants are sufficiently developed to prevent the wind from blowing the soil. If the furrows are long, a large amount of water next to the head ditch soaks into the soil and does not do the plants any good. Fifteen or twenty rods should be the greatest length for water to run on new seeding. Afterwards, when the seeding is well established, if there is sufficient water to rush over the land quickly it is not material what the distance is if the water is kept on for a period not exceeding twenty-four hours. To bring the water out of the head ditch into furrows and leave it for days to soak down near the ditch while the stream is reaching the farther side of the field is a fatal mistake.

It is probable that all of the land now suffering or likely soon to suffer from too much water could be drained at no large expense. Some of the drainage channels are there in outline. The community should be formed into a drainage district and the cost of the work be apportioned to the land receiving benefit. The members of such an

organization would be careful that too much water is not used. They should also appeal to the courts to test the right of the owners of upland and those more favorably located to endanger the crops and destroy the land values of the owners of lands of lower level. There can be no doubt that the natural drainage of the valley is ample if it is not overtaxed. The condition of the soil before water was turned onto the valley is sufficient evidence of this. A reasonable and proper use of water on any lands can never be a menace to adjoining lands. It is the careless and wasteful use of water that threatens trouble and loss of money, and a check should be put on the greed and carelessness of the slovenly irrigator.

The interests of the valley and all concerned demand that the company somewhat restrict the supply of water furnished to irrigators. The educational campaign carried on by the farmers under the Sunnyside Canal during the last two years has been of great value to the community and will continue to be of more value as the practice of other communities in the arid region is brought to the attention of all users of water.

RISE OF GROUND WATER AS SHOWN BY WELLS AND EXCAVATIONS.

When the well at Hotel Sunnyside was dug, two years ago, moist earth was found at a depth of 36 feet, and the water supply was scant. Now the water stands at 8 feet from the surface. Early in the spring a cellar was excavated in dry earth and in November the bottom was very moist. Another well, originally 40 feet deep, filled to within 30 feet, then to within 10 feet, of the top. Some old wells from 80 to 130 feet deep have gradually filled until the water in them is within 15 to 30 feet of the surface.

Mr. H. E. Perrin, of Sunnyside, dug a well in November of 1901. The water level was found at a depth of 20 feet and moist dirt at 14 feet. The water rose and the well caved in. In 1902 a well was bored at the side of the old one, water being found at 8 feet. Near by was a 10-acre tract of alfalfa which yielded three heavy cuttings and was not irrigated during the season except in a spot or two which yielded no more than that which was not watered. East of Sunnyside is a tract of land that received no water during the season and yet produced a normal crop. Late in November some of the waste ditches were carrying large streams of water, and at many places the water still appeared in cellars and on top of the ground.

The following table shows the conditions east of Sunnyside. The wells are within a radius of a mile east of the town of Sunnyside:

Water level in wells near Sunnyside.

Well No.	Date of digging.	Depth dug.	Depth to water now.	Well No.	Date of digging.	Depth dug.	Depth to water now.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	1890	80	5	6	1893	53	[b] Full.
2	1900	90	20	7	1900	15	[c] 1
3	1899	42	Full.	8	1899	40	6
4	1892	54	[a] 4	9	1898	53	[d] 15
5	1894	50	3½				

[a] Flat ground.
[b] Near No. 3, and about the same level.
[c] About 1 foot higher than No. 3.
[d] This well is on high ground and was dug in cement gravel.

THE PROSSER FALLS IRRIGATION SYSTEM.

The Prosser Falls Irrigation Company's plant is at Prosser, Wash. Water is taken from the Yakima River above Prosser Falls both for pumping and irrigation purposes. All of this water is carried 650 feet in a flume to the pumping plant, where all the water for the canals is lifted by pumps driven by water wheels. For more complete description of this plant, see former reports.[a]

The pumps not only started late in the season, but they did not run up to their full limit after August 26. The shafting was never well aligned, and when the season opened trouble was experienced from that source, requiring about $1,000 worth of repairs. The plant consists of two duplex pumps, 25-inch cylinders and 24-inch stroke, driven by two 48-inch turbines operating under a head of 12 feet. At a piston speed of 100 feet these pumps have a capacity of 1,364 cubic feet per minute. The water is forced through 1,800 feet of 28-inch steel-riveted pipe to an elevation of 100 feet, from which point it is distributed through two canals, one flowing about 3 miles downstream, while the other extends some 8 miles upstream and covers 998 acres of cultivated land. The water in the latter ditch was measured to determine the duty. During 1900 and 1901 an automatic register was used on the pumps, and the total amount of water lifted was computed from the plunger displacement. For the season of 1902 the register had been taken off, so that the investigations covered only the service under the west ditch.

During the month of April and up to May 22 there was practically no water in the ditches. The Yakima River was very low during the latter part of the season. During part of the season the pumps had to be shut down at intervals to let water enough accumulate to operate the water wheels; consequently the supply was intermittent. Under such difficulties the company undertook to prorate the flow in the ditch among the several users. The flouring mill which gets water at the same heading shut down for thirty days that there might be water

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 104, p. 247.

enough to irrigate. The alfalfa growers estimate that their crop was reduced about 1 ton per acre on account of the shortage in the water supply.

COST OF PUMPING.

The following data concerning the cost of pumping was furnished by Mr. E. F. Benson, the general superintendent of the company:

Cost of operating pumps and ditches at Prosser, Wash., from April to October, 1902:

1 day engineer, at $75 per month	$525
1 night engineer, at $45 per month	315
1 superintendent, at $60 per month	420
Oils, packing, lights, repairs, extra labor, lumber, etc., at $75 per month	525
Total	1,785

Of the $1,785 about $1,040 should be charged to operating expenses. This would make the cost of pumping 43 cents per acre-foot. This, of course, excludes the taxes, the depreciation of the plant, and the item of $1,000 spent on permanent repairs at the opening of the season, as well as the interest on $45,000, the cost of the plant.

DUTY OF WATER.

The following table shows the monthly discharge of the west line of the Prosser Ditch, and the depth to which it would cover the land on which it was used:

Duty of water under West Prosser Ditch.

[Area irrigated, 998 acres.]

Month.	Water used.	Depth of water.	Rain-fall.	Total depth of water received by land.	Month.	Water used.	Depth of water.	Rain-fall.	Total depth of water received by land.
	Acre-feet.	*Feet.*	*Foot.*	*Feet.*		*Acre-feet.*	*Feet.*	*Foot.*	*Feet.*
April	0.00	0.00	0.19	0.19	September	361.39	0.36	0.03	0.39
May	115.65	.12	.10	.22	October	401.82	.40	.03	.43
June	476.54	.48	.01	.49					
July	503.43	.50	.02	.52	Total	2,418.95	2.42	.38	2.80
August	560.12	.56	.00	.56					

UPPER RATTLESNAKE SPRING.

The Upper Rattlesnake Spring runs 0.16 cubic foot per second and serves 16 acres of alfalfa land which cut 98 tons at two cuttings. The last stand, which was used for pasture, would have cut 15 to 20 tons more. Four acres of new ground were seeded. The soil is heavier than in the lower farms and requires less water. The water from this spring is piped to the point of use.

FIG. 1.—INVERTED SIPHONS ON THE YAKIMA VALLEY CANAL COMPANY'S CANAL, WASHINGTON.

FIG. 2.—IRRIGATED ORCHARD IN SPOKANE VALLEY, WASHINGTON.

SEEPAGE AND EVAPORATION ON RATTLESNAKE CREEK.

On August 1 two weirs were placed on Rattlesnake Creek, one near the spring and the other near the farm of Mr. E. F. Benson, about $2\frac{1}{4}$ miles lower down. The following records were taken:

Losses from Rattlesnake Creek by seepage and evaporation, 1902.

Date of gaging.	Discharge.		Loss.	
	Near spring.	At farm of E. F. Benson.	Volume.	Percentage.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	
August 1	0.65	0.24	0.41	63
August 4	.77	.28	.49	64
August 19[a]	.71	.47	.24	34
August 20	.71	.28	.43	60

[a] Rainy day.

The first measurements were taken just after the weirs were set and it is probable that the flow was not entirely established.

This water served 26 acres of old alfalfa, 10 acres of new alfalfa, 1 acre of garden, 2 acres of pasture, and 2 acres of orchard, making 41 acres in all. So much water is required for new seeding that the hay did not yield an average crop, cutting only about 4 tons per acre; 15 acres only were cut the second time and 7 acres the third time.

Mr. Benson writes now that he is putting in a dam to hold flood water for irrigation purposes.

OTHER CANALS IN YAKIMA VALLEY.

The Yakima Valley Canal is owned by a cooperative company. Every user of water is a stockholder and receives water in proportion to the number of his shares. The company has 3,000 shares of stock and serves 3,000 acres. One share of stock entitles the holder to one three-thousandth part of the volume of water flowing in the canal at all times. The canal was built to serve 3,000 acres only, and the water is attached to specific lands and can be used on no other lands.

The canal was built under a contract with the owners of land to be served, and was to carry 1 cubic foot of water per second to each 160 acres of land. However, the canal has been enlarged from time to time until after all deductions are made for evaporation and seepage, the company delivers water at the rate of 1 cubic foot per second to each 100 acres. All laterals are equipped with measuring boxes with Cippoletti weirs.

The company commenced early in the fall to enlarge and extend its canal, in order to make it serve more lands and to furnish more water to present users. The first 6 miles of this work is flume, the balance ditch. In crossing Cowiche Creek two 32-inch redwood inverted

siphons are used (Pl. VIII, fig. 1). They are nearly 940 feet long and have 4.55 feet of head and about 97 feet of pressure in the lowest point. The water was originally carried in one, but a second one is being now added. These pipes are anchored in the earth near the middle, the ends are carried on trestles. This canal serves the famous Knob Hill, where property has been selling at fabulous rates, in one instance 10 acres of orchard bringing $8,000.

The real water duty can not be easily determined, yet when the original canal was carrying its maximum the writer gaged it and found 40 cubic feet per second, which gives a duty of 75 acres per cubic foot per second. Yet the shareholders are asking for more water.

So far there seems to be no serious effects on the immediate lands served from so large a use of water. What will be the effect from seepage on lands lying at a lower level the future must determine. Acres of waste and black alkali upon adjoining lands show the effects of too much water, too much subirrigation, and lack of drainage. These waste lands, once most valuable, should be a constant warning to all irrigation farmers in the Yakima Valley.

The Natchez and Cowiche Ditch Company is also a cooperative company. There are 241 shares in the company, the only difference between this company and the Yakima Valley Canal Company being that the stock of this company is not attached to specified pieces of land. It is personal property and there is more or less speculation in the shares. Not over three-fourths of the water represented by the 241 shares is used; the rest of the shares are held by speculators, so that a person can buy in the open market all the water he wants to pay for and put it on any area that he chooses. In practice there are some users of water putting a share on 20 acres, some putting it on 5 acres. The volume of water to which one share entitles its holder has been established as 8 miner's inches under 8-inch pressure, but the volume delivered has to be reduced as the season advances.

The volume of water carried by the Yakima Valley Canal is about 25 per cent greater by actual measurement than that carried by the Natchez and Cowiche Ditch. There is no accurate way of determining the area served by the Natchez and Cowiche Ditch Canal, but it is believed to be about 2,500 acres.

The R. S. & C. Irrigation Canal is operated by a cooperative company, having 75 shares of stock, only 25 or so being used. Ten miner's inches under 6-inch pressure is the maximum flow allowed per share, but frequently it has to be reduced, especially in hot weather.

The Ahtanum and Wide Hollow Ditch Company has 960 shares and its canal serves 960 acres, the water being divided pro rata.

In fact all these ditches, as well as all ditches in the valley, are cooperative and the water is distributed pro rata and the entire volume

is used. If it should be attempted to deliver a fixed volume all the time to each stockholder endless trouble would result.

SPOKANE VALLEY.

The Spokane Valley is about 40 miles long, east and west, and is from 3 to 6 miles in width. The land is level, free from brush or timber, and is traversed by many railroads and good wagon roads. The soil is a rich black granitic loam, and in the city, where water is abundant, vegetation of all kinds grows luxuriantly (Pl. VIII, fig. 2). Around the border of the valley, where there are a few small subirrigated tracts, are some of the finest orchards and gardens of the Northwest. Out in the valley, which has been partially settled for years, a different state of affairs prevails. The principal crop is fall-planted wheat, which is about the only crop which can be counted upon.

During the warm summer months the soil heats rapidly and the moisture from spring rains soon disappears. In case of a rainy summer a fair crop can be raised, but about every third year crops are an almost entire failure. However, in the foothills surrounding the valley are situated numerous lakes, where the water from the melting snows from the mountains miles away and the spring rain is held in check ready to be drawn off and distributed for irrigation when needed.

THE SPOKANE VALLEY LAND AND WATER COMPANY.

The Spokane Valley Land and Water Company operates east of Spokane, in the valley of the Spokane River, getting its water from lakes located in the highlands adjoining. For several years this company and its predecessors have been at work securing titles to water supplies and rights of way for a complete system of canals. When the season is favorable the land yields a fair return without irrigation, but in the dry seasons it can not be relied upon. The expense of supplying enough water to these lands to secure crops will likely be moderate, while the increased yield, at the very door of a city of 50,000 inhabitants, will be sure to bring good returns.

In 1900 construction work began, and a canal was built from Liberty Lake. This canal is 4 miles in length, and now waters 600 acres of land 10 miles east of Spokane city limits. In 1901 fields of alfalfa were planted, and a 5-year-old dry orchard was ditched and put into shape for irrigation. Garden truck of all kinds was raised during that year, and results were such that the usefulness and practicability of irrigation were thoroughly established.

The first of the year 1902 this land was put upon the market at $50 per acre, and from that price was advanced to $60 per acre. By July most of the 600 acres had been sold in 10, 20, and 40 acre tracts. Most of it was put into cultivation, homes built, bushes and trees set out, alfalfa planted, and general garden truck of all kinds was raised

in large quantities. The orchard watered yielded a fine crop of apples, prunes, plums, and cherries. A good yield of alfalfa was obtained, and successful crops of tomatoes, corn, potatoes, berries, tobacco, etc., were marketed. The few tracts which the company now owns are held at $100 per acre, and improved land at from $125 to $200 per acre. Term of sales are one-fifth down and four annual payments, with interest on deferred payments at 7 per cent.

FISH LAKE CANAL.

Last year a canal was completed which will distribute water from Fish Lake over 5,000 acres of rich land between Houser Junction and Rathdrum, 25 miles from Spokane. It has just been put upon the market, and a part will be sold at $75 per acre, with the purchaser's agreement that it will be put into cultivation and improved. The canal as now built is 7 miles long, from 8 to 12 feet in width, and will carry 9 cubic feet of water per second. The canal can be enlarged when necessary. The company owning this canal also has rights to water from Newman, Sucker, and Hayden lakes and from the Spokane River. A short canal has been constructed from Newman Lake, and work is being done on others. When the canal system is entirely developed, it is estimated that 40,000 acres will be watered.

IRRIGATION INVESTIGATIONS IN MONTANA, 1902.

By Samuel Fortier,

Director and Irrigation Engineer Montana Agricultural Experiment Station.

The past season was in nearly every respect a favorable one for the Montana farmer. The spring was early, with more than an average amount of rainfall, and the autumn was mild and dry. The water supply was also plentiful in most sections and the irrigation farmer was made happy in being permitted to use more water than in former years. This fact may be observed in the following comparisons between the quantities of water used under a few of the canals of the State in 1901 and in 1902.

Comparison between quantities of water supplied by canals in 1901 and 1902.

Canal.	Location.	Depth of water applied over the surface.	
		1901.	1902.
		Feet.	*Feet.*
Big Ditch	Yellowstone County	2.56	3.68
Republican	Ravalli County	3.35	4.41
Hedge	do	3.97	5.76
Ward	do	2.41	2.49
Skalkaho	do	4.68	6.79
Gird Creek	do	1.45	3.50
Middle Creek	Gallatin County	2.00	1.15

The above table shows that considerably more water was used during the past season than in the year preceding. With the exception of Middle Creek Canal, the depths of water over the area irrigated are in every case greater. The total extent of land irrigated by these seven canals is over 42,000 acres, or nearly one-twentieth part of the irrigated area of the State.

In consequence of the favorable season and a plentiful supply of irrigation water the products from both valley and bench lands were abundant, and commanded good prices in the local markets. The yields of grain throughout the Gallatin Valley in particular were phenomenal. The truth of this statement is made apparent by the following figures, which give the yields of various cereals on a few of the grain plats on the experiment station farm:

Grain yields, Montana Experiment Station, 1902.

	Bushels per acre.
Wheat:	
Glyndons (768)	72.5
Wild Goose	66.0
Pringle Champion	77.0
Eldorado	75.5
Kubanka	76.5
Wellman Fife	72.5
Oats:	
Improved American	165.0
Progress	166.8
Wide Awake	172.5
Early Everett	174.3
Barley:	
Manhattan	80.0
Mandscheuri	81.9
Italian	90.0
New Zealand	93.8
Guy Male	96.9

For four consecutive years irrigation investigations have been carried on in this State through the joint efforts of the U. S. Department of Agriculture and the Montana Experiment Station. Last spring the field of operations was considerably enlarged, owing to the liberality of the seventh legislative assembly of Montana, which appropriated the sum of $2,000 for irrigation investigations. This sum, in addition to the funds obtained from the Office of Experiment Stations, United States Department of Agriculture, and a small amount from the irrigation department of the Montana Experiment Station, was all expended in 1902.

The scope of the investigation included a hydrographic survey of Gallatin Valley, determining the capacities of the natural streams and irrigation canals, discussing the status of water rights, and describing the methods used in irrigation. This report is now nearly completed.

The experiments relating to the duty of water and seepage losses from canals were continued and the results are herein summarized. In addition to the foregoing a series of farmers' bulletins on irrigation topics is being published by the Montana Experiment Station. Of this series No. 1 is on farmers' weirs; No. 2 is on the duty of water in Montana; No. 3 (in press) is on the grades and capacities of irrigation ditches and canals.

In the work of stream and canal measurements, in conducting field experiments, and in office computation the writer has been ably assisted by Arthur P. Stover, assistant in irrigation investigations; J. S. Baker, assistant professor in civil engineering, Agricultural College of Montana; and by several of the advanced students in civil engineering of that institution, among whom may be named H. B. Waters, F. L. Tavenner, G. T. Morris, J. H. Sloan, W. B. Freeman, C. D. Flaherty, F. M. Brown, L. A. Cowan, and Clinton E. Lamme.

DUTY OF WATER UNDER WEST GALLATIN RIVER.

The irrigation season in Gallatin Valley extends from about the middle or last of May until about August 15. This length of season applies, in general, to the whole valley. The first crops to receive water in the spring are pasture and meadow, clover and alfalfa. After these have received a sufficient watering, attention is given to the grain. As this is the principal crop of the valley, the period devoted to grain irrigation occupies a large part of the season. After the first irrigation of grain and after the first crops of clover and alfalfa are removed, the water is again applied to the latter for a second crop.

There are usually from one to three applications of water to the grain crops, and one each for the two crops of clover and alfalfa. This, however, is largely influenced by the amount and time of the rainfall. In the season of 1902 the rainfall was sufficient and occurred at such times that one irrigation for each crop of clover and alfalfa was sufficient.

Little has previously been done in the way of a study of the use of water from the West Gallatin River. Such results as exist have been obtained by private parties, and on a small scale, and, consequently, have but a local application. In the spring of 1902 extended investigations were planned, having for their object the determination of the duty of water under canals which would represent the varied conditions of soil, methods of irrigation, and canal management. In this connection it was necessary to study the seepage from the canals, as this very materially affects the duty of water. According to the general plan, the High Line Canal of the West Gallatin Irrigation Company, the Kughen Ditch, and the Weaver & Stone Ditch were selected. The first represents the larger corporation canals, and since it carries water a long distance before any is diverted into laterals, conditions were favorable for determining seepage losses. The second is representative of the medium-sized ditches whose waters are carried but short distances before being distributed into laterals, thus eliminating the large losses due to seepage. The last is representative of the small individual or partnership ditches which head on the lower sections of the river.

A water register was placed in each of the canals and a continuous record made throughout the entire irrigation season.

HIGH LINE CANAL.

A water register was placed in this canal about 2½ miles below the intake in what is known as the Todd Flume. This flume, which is 30 feet long and 13⅓ feet wide inside, was used as a rating flume.

According to the report of Mr. E. C. Kinney, superintendent of the West Gallatin Irrigation Company, there were 2,343 acres irrigated by the water which passed through the Todd Flume. On this basis

the duty of water has been determined and is given in the following summary:

Duty of water under the High Line Canal, 1902.

Duration of irrigation season (May 24 to August 31)	days	100
Area irrigated	acres	2,343
Water used:		
May	acre-feet	568.57
June	do	3,612.87
July	do	5,555.42
August	do	2,728.98
		12,465.84
Average depth of water applied	feet	5.32
Depth of rainfall during season[a]	foot	.39
Total depth of water received by land	feet	5.71

From the above figures it is found that throughout the irrigation period of one hundred days the average flow of the canal at Todd's Flume was approximately 62 cubic feet per second, or 2,480 Montana miner's inches. The duty of water on this basis is 37.8 acres per cubic foot per second, or 0.945 of an acre per miner's inch. This is the duty of the water based on the amount entering the head gates of the canal. From seepage tests it was found that there was a loss in the first 26.5 miles of 26.67 per cent of the amount entering the head. It is estimated that to this should be added an additional loss of about 8.33 per cent, the amount lost in the lateral and distributary systems. This would make a total loss of 35 per cent. This expressed in other terms is 79.93 acre-feet per day. On this basis the duty is 58.13 acres per cubic foot per second, or 1.45 acres per miner's inch.

KUGHEN DITCH.

As there was no flume in this ditch which could be used for rating the canal one was built for that purpose, and set about one-half mile below the point of diversion. This was but 300 yards above the first lateral. The canal was of a uniform cross section and the alignment good, and other conditions favorable for accurate rating. The flume was 10 feet wide and 14 feet long, and placed level in the bed of the canal. Under average conditions this flume carried a depth of 2½ feet of water.

From a careful transit and stadia survey the area of land irrigated during the season of 1902 was 1,564.85 acres. Of this area 12.39 acres poduced wheat, 899.07 acres barley, 422.63 acres oats, 121.68 acres flax, 3.44 acres clover, 80.39 acres timothy, and 25.25 acres pasture.

[a] Rainfall assumed to be the same as at the Government Weather Bureau Station at Bozeman, Mont.

Duty of water under Kughen Ditch, 1902.

Duration of irrigation period (June 4 to August 16) ....days..	74
Area irrigated ....acres..	1,564.85
Water used:	
June ....acre-feet..	2,643.34
July ....do....	3,603.47
August ....do....	1,078.99
	7,325.80
Average depth of water applied....feet..	4.68
Depth of rainfall during season ....foot..	.33
Total depth of water received by land....feet..	5.01

For the period of seventy-four days the average flow of the canal through the rating flume was 49.93 cubic feet per second. The duty in acres per cubic foot per second on this basis is 31.34 acres, or 0.78 acre per miner's inch.

WEAVER & STONE DITCH.

This ditch heads 6 miles below the head of Kughen Ditch on the east side of the West Gallatin River. A rating flume 4.7 feet wide and 8 feet long was placed in the ditch about 600 feet below the head.

The area of land actually irrigated under the Weaver & Stone Ditch in 1902 was determined by a transit and stadia survey. The areas seeded to various crops are as follows: Barley, 38.12 acres; wheat, 74.69 acres; oats, 4.59 acres; clover, 3.21 acres; alfalfa, 53.31 acres; wild hay, 17.22 acres; total, 191.14 acres.

The duty of water on the basis of above area and flow of the ditch at the flume is as follows:

Duty of water under the Weaver & Stone Ditch, 1902.

Duration of irrigation season (June 1 to August 16) ...days..	77
Area irrigated ....acres..	191.14
Water used:	
June ....acre-feet..	555.87
July ....do....	346.40
August ....do....	227.86
	1,130.13
Average depth of water applied....feet..	5.91
Depth of rainfall during season ....foot..	.35
Total depth of water received by land....feet..	6.26

The average flow in cubic feet per second at the rating flume was 7.38. The duty of water on this basis is 25.90 acres per cubic foot per second, or 0.65 of an acre per miner's inch.

This would appear to be a very low duty of water. But in a distance of 4½ miles from the rating flume to the point of distribution

the ditch loses approximately 50 per cent of its volume. Upon this basis the duty expressed in actual quantity would be 3.31 acre-feet per acre, or, in terms of continuous flow, 51.8 acres per cubic foot per second, or 1.3 acres per miner's inch.

DUTY OF WATER IN THE YELLOWSTONE VALLEY.

BIG DITCH.

For the past two years the amount of water used under what is known as the Big Ditch, in Yellowstone County, Mont., has been determined. This is one of the largest canals in the State. In July, 1901, its capacity at Tilden's ranch, about 5 miles below the head, was 11,960 miner's inches, and in the same month of 1902 it was 14,480 miner's inches, the increased flow during the past season being due to certain improvements and enlargements that were made before the beginning of the last irrigating season.

This canal was begun in 1882 by the Minnesota and Montana Land and Improvement Company and completed several years later at a total cost of $110,000. It was maintained and operated by this company until May, 1900, when it was purchased by the farmers who owned land under it. The price paid was $64,000, which was divided into 6,400 shares of the par value of $10 each. In 1902 there were 132 stockholders, who owned on an average 47 shares each. The management is vested in a board of directors composed of 7 stockholders who are elected by ballot at each annual meeting of the stockholders. The maintenance and operation of the canal and diversion dam as well as the division of the water is under the direct supervision of a superintendent who is employed by the board of directors.

The water is distributed to the various laterals through salt-glazed vitrified pipes, which vary in size from 6 to 12 inches in diameter and extend through the embankment of the canal. On the inner end of each outlet pipe is inserted the O'Donnell patent gate, which serves the double purpose of controlling and measuring the flow.

The areas of land irrigated under the Big Ditch during the seasons of 1901 and 1902 were obtained by a house-to-house canvass. Each stockholder when interviewed made a careful estimate of the acreage under different kinds of crops, the amount of waste land, and the total extent of his farm. The following table has been prepared from several hundred of these individual estimates:

Acreage of crops irrigated under the Big Ditch, Montana, 1901 and 1902.

Kind of crop.	1901.	1902.	Kind of crop.	1901.	1902.
	Acres.	*Acres.*		*Acres.*	*Acres.*
Alfalfa	8,270	8,894	Garden	550	610
Meadow[a]	6,309	6,243	Corn	352	358
Oats	1,885	3,117			
Wheat	778	816	Total	18,144	20,038

[a] Meadow comprised timothy and blue joint as well as irrigated pasture.

As has been stated, the carrying capacity of the canal was considerably increased before the beginning of the season of 1902, and the additional volume carried not only supplied the needs of the consumers but provided a surplus, which was wasted on the farms and at the waste gates on Valley Creek, Canyon Creek, and at the lower end of the canal. The flow over these waste gates was considerable during the month of September. The following tables show the duty of water under this canal for the two seasons:

Duty of water under the Big Ditch, Yellowstone County, Mont., 1901.

Duration of irrigation season (May 14 to August 31)..days..	110
Area irrigated ....acres..	18,144
Water used:	
May ....acre-feet..	6,211.80
June ....do....	9,980.20
July ....do....	16,242.90
August ....do....	14,069.70
Total	46,504.60
Average depth of water applied ....feet..	2.56

Duty of water under the Big Ditch, Yellowstone County, Mont., 1902.

Duration of irrigation season (May 14 to September 30) .days..	140
Area irrigated ....acres..	20,038
Water used:	
May ....acre-feet..	10,197.70
June ....do....	15,580.10
July ....do....	19,134.50
August ....do....	17,468.90
September..........do....	11,442.90
Total	73,824.10
Average depth of water applied ....feet..	3.68

DUTY OF WATER IN THE BITTER ROOT VALLEY.

For three years investigations have been conducted in the Bitter Root Valley to determine the quantity of water used in irrigation and the various losses in its conveyance. The greater part of the work was performed on the Bitter Root stock farm, the property of the late Hon. Marcus Daly. The conditions on this farm are favorable for such investigations. Through the cooperation of the superintendent, Mr. P. J. Shannon, and the irrigation engineer, Mr. M. D. Kippen, accurate data have been secured in regard to the area of the land irrigated and the kinds of crops raised.

The results for the past season on the five canals of the Bitter Root stock farm, described in the report for 1901, show an increased area

irrigated and a larger use of water. In 1901 the total area irrigated under the five canals was 15,763 acres, while in 1902 it was 17,575 acres. The amount of water used when measured in depth over the surface was 3.17 feet in 1901 and 4.44 feet in 1902. The use of a larger quantity of water during the past season is due to a more abundant supply in the Bitter Root River and to the long dry season.

REPUBLICAN CANAL.

The costly head gates and diversion dam of the Republican Canal are located on the Bitter Root River near the junction of the tributary known as Sleeping Child. This canal for the first 5 miles has a bottom width of about 12 feet and an average depth of about 3 feet on a grade of 5 feet to the mile. For the next three miles it has nearly the same slope as that of the river, or over 40 feet per mile. The canal decreases in width and volume as its distance from the head increases, and is quite narrow from the eighth to the twentieth mile. The lower portion is located on a grade of 8 feet to the mile. In 1901 the flow of this canal varied from 2,000 to 3,200 miner's inches. In 1902 the highest flow was 3,927 miner's inches and the average for the season was nearly 2,200 miner's inches.

The following table shows the water supplied each month during the season of 1902 and the depth to which this would cover the land irrigated:

Duty of water under the Republican Canal, Ravalli County, Mont., 1902.

Duration of irrigation season (May 11 to September 30)	days	133
Area irrigated	acres	4,850
Water used:		
May	acre-feet	3,442.20
June	do	4,371.50
July	do	3,995.50
August	do	5,825.80
September	do	4,251.30
Total		21,886.30
Average depth of water applied	feet	4.41

HEDGE CANAL.

The Hedge Canal diverts water from the Bitter Root River a number of miles above the Republican Canal. This canal is 24 miles long and irrigated during the past season 5,420 acres of first bench lands immediately above the areas covered by the Republican Canal. The upper portion skirts the river and consists chiefly of flumes and inverted siphons. There are about 5 miles of flumes and 1,100 feet of

redwood stave pipe. The greatest flow during the season of 1902 was 5,092 miner's inches and occurred June 21 and 22. The following table shows the duty of water for 1902:

Duty of water under the Hedge Canal, Ravalli County, Mont., 1902.

Duration of irrigation season (April 14 to September 30) . . days . .	133
Area irrigated . . . acres . .	5,420
Water used:	
April . . . acre-feet . .	1,721.50
May . . . do . . .	5,438.60
June . . . do . . .	6,243.40
July . . . do . . .	5,955.50
August . . . do . . .	6,276.90
September . . . do . . .	5,626.20
Total . . .	31,262.10
Average depth of water applied . . . feet . .	5.76

WARD CANAL.

The Ward Canal diverts water from the Skalkaho Creek, a tributary of the Bitter Root River. In 1902 this canal irrigated 3,985 acres of bench lands located above the Hedge Canal. It is 7 miles long, has a bottom width of about 8 feet, and is built on a grade of 5.28 feet per mile. The greatest flow during 1902 was 2,800 miner's inches and occurred June 23 to July 3. The duty of water for 1902 is given in the following table:

Duty of water under Ward Canal, 1902.

Duration of irrigation season (April 18 to September 30) . . days . .	157
Area irrigated . . . acres . .	3,985
Water used:	
April . . . acre-feet . .	230.30
May . . . do . . .	2,318.20
June . . . do . . .	3,751.80
July . . . do . . .	2,565.90
August . . . do . . .	806.50
September . . . do . . .	253.00
Total . . .	9,925.70
Average depth of water applied . . . feet . .	2.49

SKALKAHO CANAL.

This canal, which is also supplied from Skalkaho Creek, is about 7 miles long, of which 2½ miles consist of flumes 4 feet 8 inches wide inside by 2 feet 8 inches high. The grade is 5.28 feet per mile throughout. The greatest flow for the season of 1902 was 2,796 miner's

inches and occurred July 1 and 2. The duty of water is shown in the following table:

Duty of water under Skalkaho Canal, 1902.

Duration of irrigation season (April 8 to September 30) . . days . .	167
Area irrigated . . . acres . .	1,975
Water used:	
April . . . acre-feet . .	469.20
May . . . do	2,097.10
June . . . do	3,336.30
July . . . do	3,334.50
August . . . do	2,582.10
September . . . do	1,617.60
Total . . .	13,436.80
Average depth of water applied . . . feet . .	6.79

GIRD CREEK CANAL.

The entire flow of Gird Creek is utilized for irrigation purposes during the summer months by means of two canals. Of these, the South Gird Canal is the higher and irrigates land beyond the end of the Skalkaho Canal. South Gird Canal, or ditch, is 6 feet wide on the bottom, 2 feet deep, and is built on a grade of 5.28 feet per mile. North Gird Canal is of about the same dimensions and irrigated the land lying north of Gird Creek and above the Ward Canal. During the past season the maximum flow of the North Canal was 1,128 miner's inches and of the South Canal 1,660 miner's inches. The following table gives the duty of water under the North Gird Creek Canal:

Duty of water under the North Gird Creek Canal.

Duration of irrigation season (April 9 to September 30) . . . days . .	162
Area irrigated . . . acres . .	1,345
Water used . . . acre-feet . .	4,710
Average depth of water applied . . . feet . .	3.50

AMOUNT OF WATER USED IN FIELD IRRIGATION.

For the past four seasons experiments have been made in different parts of Montana to ascertain the amount of water used in field irrigation. An individual field presents fewer complications than a tract of land under a canal for the reason that all losses due to conveyance are eliminated. Only the water which enters the highest part of the field is measured. Of course a part of this supply may be wasted by unskilled application, but an effort has been made to make tests only on the fields of the most careful irrigators. In this connection it may be well

to state that no attempt has ever been made to control or limit the amount used. The proprietor of the field, or his agent, was at liberty to use as much water as he deemed necessary. In consequence, the results show the usual quantities of water applied under the best practice in this State. On about fifty of such experiments the average depth of water applied has been 18 inches, or 1½ acre-feet per acre irrigated.

In beginning the field tests in the spring of 1902 advantage was taken of the trapezoidal weirs already in place which had been used for a similar purpose in previous years. These weirs comprised several in the Bitter Root and Gallatin valleys, and the respective fields for which water was measured over these weirs have been fully described in previous reports.

Nos. 1 to 7, inclusive, of the following experiments were made on the experiment station farm. On a portion of this farm the soil is rather shallow and is underlain by coarse gravel and cobbles. On the more fertile portions there are from 5 to 9 inches of vegetable loam, 15 to 20 inches of clay loam, 30 to 40 inches of clay marl, and an unknown depth of river wash. The field laterals were laid out with an engineer's level on a grade of from 0.5 inch to 1.25 inches per rod and about 60 feet apart.

Duty of water on barley, experiment No. 1.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 14–17	July 26–30	....
Duration of irrigation ... hours	58.5	29.3	87.8
Area irrigated ... acres	19.8	19.8	19.8
Water used ... acre-feet	10.89	8.32	19.21
Average depth of water applied ... foot	.55	.42	.97
Rainfall ... do	....	....	.64
Total depth of water received during growth ... feet	....	....	1.61
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second	2.25	3.44	....
Average distance between field laterals ... feet	....	....	60

Duty of water on rotation plats, experiment No. 2.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 26–27	July 18–19	....
Duration of irrigation ... hours	17	23.5	40.5
Area irrigated ... acres	6	6	6
Water used ... acre-feet	3.24	3.02	6.26
Average depth of water applied ... feet	.54	.50	1.04
Rainfall ... foot	....	....	.64
Total depth of water received during growth ... feet	....	....	1.68
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second	2.31	1.55	....

Duty of water on wheat, experiment No. 3.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 22–23	July 25–31	....
Duration of irrigation ... hours..	36	54.3	90.3
Area irrigated ... acres..	5.62	5.62	5.62
Water used ... acre-feet..	7.26	6.45	13.71
Average depth of water applied ... feet..	1.29	1.15	2.44
Rainfall ... foot..	....	....	.72
Total depth of water received during growth ... feet..	....	....	3.16
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second..	2.44	1.44	....
Average distance between field laterals ... feet..	....	....	60

Duty of water on oats, experiment No. 4.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 24–25	July 17–18	....
Duration of irrigation ... hours..	14	29.5	43.5
Area irrigated ... acres..	3.38	3.38	3.38
Water used ... acre-feet..	1.81	2.50	4.31
Average depth of water applied ... feet..	.54	.74	1.28
Rainfall ... foot..	....	....	.54
Total depth of water received during growth ... feet..	....	....	1.82
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second..	1.56	1.03	....
Average distance between field laterals ... feet..	....	....	60

Duty of water on clover, experiment No. 5.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 3–6	July 13–17	....
Duration of irrigation ... hours..	43	65.16	108.16
Area irrigated ... acres..	9.72	9.72	9.72
Water used ... acre-feet..	6.17	9.93	16.10
Average depth of water applied ... feet..	.63	1.02	1.65
Rainfall ... foot..	....	....	.78
Total depth of water received during growth ... feet..	....	....	2.43
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second..	1.74	2	....
Average distance between field laterals ... feet..	....	....	77

Duty of water on oats, experiment No. 6.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 11–14	July 19–22	....
Duration of irrigation ... hours..	55.5	77.5	133
Area irrigated ... acres..	8.93	8.93	8.93
Water used ... acre-feet..	8.46	7.31	15.77
Average depth of water applied ... feet..	.95	.82	1.77
Rainfall ... foot..	....	....	.54
Total depth of water received during growth ... feet..	....	....	2.31
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second..	1.84	1.14	....
Average distance between field laterals ... feet..	....	....	60

Duty of water on alfalfa, experiment No. 7.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 11–17	July 17–18	....
Duration of irrigation ....hours..	10.25	24	34.25
Area irrigated ....acres..	4.02	4.02	4.02
Water used ....acre-feet..	1.58	2.48	4.06
Average depth of water applied ....feet..	.39	.61	1
Rainfall ....foot..	....	....	.78
Total depth of water received during growth ....feet..	....	....	1.78
Number of irrigators	1	1	....
Average head of water used ....cubic feet per second..	1.87	1.25	....
Average distance between field laterals ....feet..	....	....	71

Experiment No. 8.

For four consecutive years the quantity of water applied to a field belonging to Mr. J. S. Patterson, situated 2 miles south of the experiment farm, has been determined. The total amount of water received, including both rainfall and irrigation, during the four years is in brief as follows:

Year.	Crop.	Depth of water.	Year.	Crop.	Depth of water.
		Feet.			*Feet.*
1899	Oats	1.72	1901	Clover	1.57
1900	....do	1.23	1902	....do	1.78

The results for 1902 are given in the following table:

Duty of water on clover, experiment No. 9.

	First irrigation.
Date of irrigation	June 17–24
Duration of irrigation ....hours..	192
Area irrigated ....acres..	27.84
Water used ....acre-feet..	27.83
Average depth of water applied ....foot..	1
Depth of rainfall ....do....	.78
Total depth of water received during growth ....feet..	1.78
Number of irrigators	1
Average head of water used ....cubic feet per second..	1.75
Average distance between field laterals ....feet..	80

A brief summary of three experiments, Nos. 10 to 12, inclusive, made on fields in the Bitter Root Valley for 1902, are herein recorded:

Summary of experiments Nos. 10 to 12.

Kind of crop.	Area irrigated.	Length of irrigation season.	Rainfall in depth over surface.	Irrigation in depth over surface.	Total depth received.
	Acres.		*Foot.*	*Feet.*	*Feet.*
Apple orchard	40.0	Apr. 25–Aug. 31	0.66	1.77	2.43
Red clover	161.7	.....do	.66	1.30	1.96
Do	102.0	.....do	.66	3.95	4.61

The above experiments in the Gallatin Valley show that the average quantity of water for all crops for 1902 was 1.46 acre-feet, or practically the same as that shown by previous reports, so that the conclusion seems justified that in Gallatin Valley a depth of 18 inches of water is sufficient to raise any of the ordinary farm crops. Experiments Nos. 10 to 12 in the Bitter Root Valley show that more water was used there than in the Gallatin Valley in 1902, but these experiments are not a sufficient basis for general conclusions as to that valley.

IRRIGATION SYSTEMS ON STONY CREEK, CAL.

By W. T. Clarke and C. W. Landis.

INVESTIGATIONS, 1901.

The notes here presented are the results of an investigation of the Stony Creek (Cal.) region, made primarily with the idea of obtaining as clear a knowledge as possible of the conditions in regard to the use of water now existing on that stream. The scope of this investigation, however, has been broadened so as to include not only the present use of water, but to show also the agricultural and horticultural conditions in the region and its possibilities which are dependent entirely upon the use of water. While this investigation has been conducted as thoroughly as time would permit and covers the whole length of the creek, the region around Orland, Cal., receives more extended notice than any other portion of the country adjacent to the creek, owing to the fact that in this Orland region water has been used more extensively than in any other one part of the region studied.

Stony Creek rises in the Coast Range in the western and northern part of Colusa County, Cal.; takes a northerly course of some 24 miles in the western part of Glenn County; then easterly for some 6 miles in Tehama County; then southeasterly through Glenn County some 18 miles to the Sacramento River. The creek runs through the foothill region of the Coast Range of mountains until the last course through Glenn County, where it enters the plains region west of the Sacramento River (fig. 5).

The town of Orland is situated on the south of the creek some 14 miles from its mouth, in an irrigated section set down in the midst of vast grain fields and a section that, save for water, would to-day be a grain field of small value supporting a limited population. The region shows very conclusively the beneficial effect of the use of water; and the orange and lemon trees just coming into bearing, the orchards of deciduous fruits, and the alfalfa fields, all immediately surrounding the town, give a forecast of what under a more extended irrigation system may de done here in the future (Pl. IX).

Under the Wright law an irrigation district, known as the South Side Irrigation District, was established here in 1888. It embraced 26,000 acres, and bonds for $100,000 were issued but not sold. Assessments aggregating $6,000 were collected, but the district was allowed to die.

The region is now covered by a ditch taking its water from Stony Creek at a point on the south side of the creek some 10 miles above the town. This ditch, which is owned by a corporation, the Stony Creek Irrigating Company, is 10 miles long, has an average cross-section of 10 by 2 feet, and a grade varying from 3.2 to 5 feet per mile. It was constructed in 1891–92, and the construction cost was some $9,000. Besides this, some $4,250 was expended for rights of way. The cost of administration is from $700 to $1,000 more per annum than the present income from the ditch. The title to the water for this ditch is based on a notice posted and filed with the recorder of Glenn

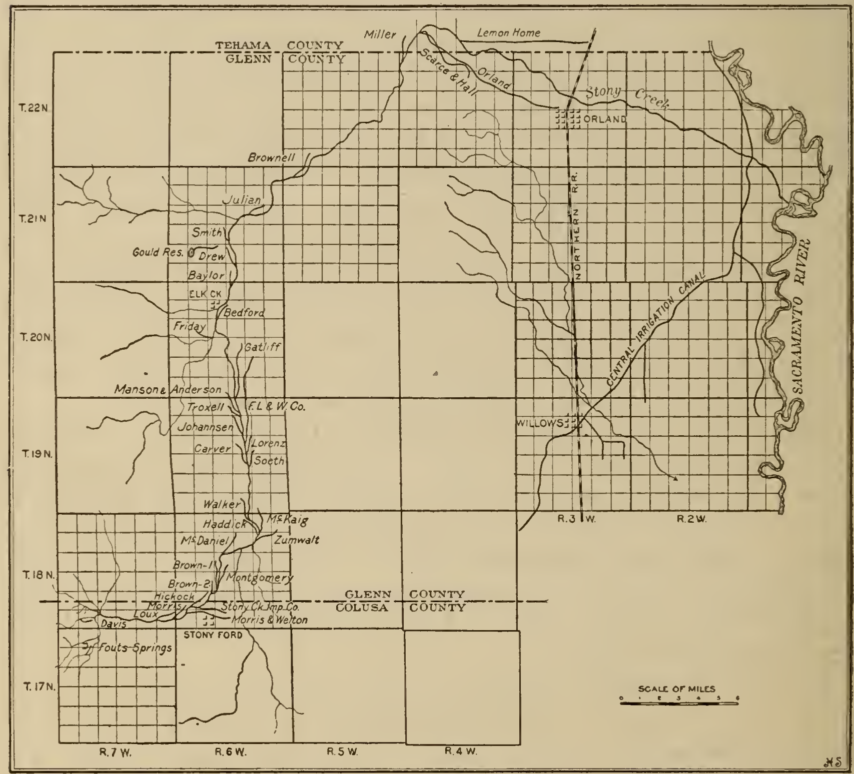


FIG. 5.—Map of irrigation canals on Stony Creek, California.

County, and this notice calls for "100,000 miner's inches of water." The ditch covers some 20,000 acres of land. At present water is used on some 225 acres, of which 80 acres are in alfalfa and the balance in citrus and deciduous fruits. The gross value of the alfalfa crop is some $2,400 per annum. There are some 20 acres of citrus fruits now coming into bearing, and while enough fruit of this character has been ripened to demonstrate the fact that a good, clean, first-class product can be grown, not enough has yet been ripened to show the commercial value of the enterprise. The deciduous fruits (including grapes)

FIG. 1.—IRRIGATING AN ORCHARD JUST SET OUT.

FIG. 2.—IRRIGATED ORANGE TREES 5 YEARS OLD, ORLAND, CAL.

The region is now covered by a ditch taking its water from Stony Creek at a point on the south side of the creek some 10 miles above the town. This ditch, which is owned by a corporation, the Stony Creek Irrigating Company, is 10 miles long, has an average cross-section of 10 by 2 feet, and a grade varying from 3.2 to 5 feet per mile. It was constructed in 1891–92, and the construction cost was some \$9,000. Besides this, some \$4,250 was expended for rights of way. The cost of administration is from \$700 to \$1,000 more per annum than the present income from the ditch. The title to the water for this ditch is based on a notice posted and filed with the recorder of Glenn

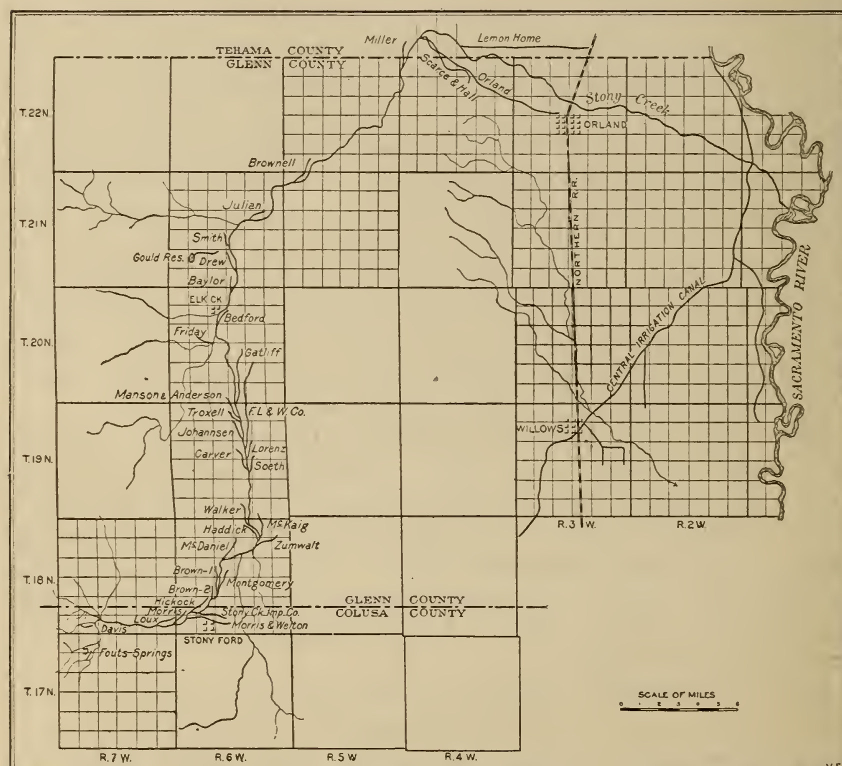


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FIG. 1.—IRRIGATING AN ORCHARD JUST SET OUT.

FIG. 2.—IRRIGATED ORANGE TREES 5 YEARS OLD, ORLAND, CAL.

FIG. 1.—DIVERTING DAM OF THE LEMON HOME DITCH, CALIFORNIA.

FIG. 2.—HEAD GATE, LEMON HOME DITCH, CALIFORNIA, SHOWING WASHOUT CAUSED BY WINTER HIGH WATER.

cover some 125 acres, and the product from this area for 1900 was 10 tons of Muscat grapes, and about 10 carloads of dried fruits—apricots, peaches, and prunes. These fruits are entirely dependent on water for bringing them to perfection.

As for alfalfa, one or two crops may be grown without irrigation, but for full crops water here, too, is a necessity. The grain section surrounding the town is, as before stated, of a large area, and a careful comparison of figures shows the yield to average some 950 pounds of wheat to the acre. Eighty-five cents per 100 pounds being an average price, the gross yield here per acre is about $8.10.

By way of comparison it is interesting to note the value of irrigated alfalfa. As previously noted the yield from 80 acres of alfalfa is $2,400, or $30 per acre per year, and the proportion is $30 to $8.10 in favor of alfalfa.

Other agricultural products shipped from Orland in 1900 were as follows: Hogs, on foot, 50 carloads; sheep, 200 cars; sheep wool, 6 cars; Angora goats wool, 4 tons; grain, 80,000 to 100,000 sacks.

The Angora goat industry is carried on some 25 miles north of Orland, the goats being pastured on the brushy mountain sides of the Coast Range. The industry may be said to be in its infancy as yet. The hogs noted as shipped out are fattened in grain fields near Orland. Sheep are pastured on the rolling land contiguous to Stony Creek in the spring, and taken to the mountains for the rest of the year. These industries require large areas with a sparse and scattered population.

The poultry industry is credited with some 200 cases of eggs, and some 10 to 20 tons of dressed turkeys were shipped out. The industry is carried on as a side issue on the large grain ranches, the turkeys being herded in the stubble fields and on the waste land, where they fatten well.

These various industries are interesting as showing the possibilities of the country, but they have a further significance when viewed as industries not fully dependent on irrigation to be to a certain extent successful. A comparison of the areas of land covered by these various industries with the areas of which industries dependent on water can be sucessfully carried on indicates that the irrigated section is the one with the denser population; shows that under the average conditions 1 acre of irrigated land has a supporting value equal to from 4 to 10 acres of unirrigated land. So much for the Orland district.

SCARCE & HALL DITCH.

This ditch heads at the same point as the Orland Ditch and is one of the oldest ditches on Stony Creek. Measurements of the flow at the head of this ditch were taken on July 9, 1901, and reported in the table at the end of this report.

LEMON HOME DITCH.

This ditch takes its water from Stony Creek at a point some 3 miles down the creek from the head of the Orland Ditch. (Pl. X.) It is the property of a stock company. It was partly constructed in 1897 and the balance in 1900 and cost $10,000. It is 6 miles long with an average cross section of 20 by 2.5 feet. The grade is 4 feet to the mile. The branches of this canal have a cross section of 10 by 2.5. It covers at present some 3,000 acres and can be developed to cover some ten times this amount of land. There are irrigated at present 50 to 60 acres. Fifteen acres of this are planted to orange trees and the balance to alfalfa. The alfalfa yield to the acre is from 4½ to 5 tons per year, with a value of $30. Wheat, not irrigated, yields 800 pounds to the acre, which at 85 cents per hundred means a gross return of $6.80 per acre. Here, as at Orland, we note the smallest value irrigated crop to be worth some four times the unirrigated crop value on similar land. The citrus trees here are not yet of bearing age. The company owning this ditch has title to the water through notice posted and filed with the county recorder. Water is found, as at Orland, at a depth of about 30 feet.

W. B. MILLER DITCH.

This ditch heads on the north side of Stony Creek, some 5 miles above the head of the Lemon Home Ditch. It was built in 1894, at a cost of $600. It is 1 mile long and averages 2 feet wide by 1 foot deep and is run on no particular grade, but follows the country fall. It covers 25 acres of bottom land, of which 10 acres are planted to alfalfa and the balance to garden truck. The alfalfa runs between 4 and 5 tons to the acre per year, being valued at about $25. As for the garden truck, values could not be obtained for comparison, as the ground is worked by Chinese renters. The ditch is owned by an individual and the title to the water rests in simple appropriation and use, the owner of the ditch taking "what water he wants." The cost of maintaining this ditch is $25 per year. Water is found here at a depth of from 20 to 30 feet.

I. W. BROWNELL DITCH.

The Brownell Ditch heads on the north side of Stony Creek, some 8 miles above the head of the Miller Ditch. It was built in 1891 and 1892 at a cost of $1,200. It is 1 mile long with a width of 4 feet and an average depth of 5 feet, and has a grade of from 6 to 7 feet per mile. It irrigates 45 acres of alfalfa, which yields three crops a year at about 1½ to 2 tons to the cutting. The value of each cutting is the same as that of one crop of wheat, which again gives the irrigated crop the advantage as to value. The ditch is under private ownership, and

the title to water is based on simple appropriation and use. The cost of maintenance is $100 per year. The depth to water is from 30 to 35 feet.

JULIAN DITCH.

This ditch heads on the west side of Stony Creek, 6 miles above the head of the Brownell Ditch. It was constructed at an unknown cost by Chinese renters in 1893, and is 1 mile long, 4 feet wide, 2½ feet deep, and follows the country fall—about 7 feet to the mile. It irrigates 300 acres of land, of which 10 acres are planted to vegetables and the balance to deciduous fruit trees. The returns from this land could not be obtained from the tenants. The same land planted to wheat runs about 950 pounds to the acre unirrigated. This ditch is a private ownership affair, and the title is based on appropriation and use, the amount claimed being "what the ditch owner wants." Cost of maintenance could not be obtained from the Chinese tenants. Water is here found at a depth of 15 feet.

ELLIS DITCH.

One mile above the Julian Ditch Grindstone Creek empties into Stony Creek from the west. The Ellis Ditch takes water from this creek and is used to irrigate a number of acres of alfalfa. Data in reference to this ditch could not be obtained. The alfalfa here runs 1½ to 2 tons to the cutting, with three crops cut per year.

SMITH DITCH.

About a mile above the mouth of Grindstone Ditch, on the west side of Stony Creek, is the head of Smith Ditch. This ditch was built in 1895 at a cost of $25, and is notable from the fact that water was raised to it from the creek by a water wheel. The ditch has not been in use for the past two years (1900–1901) and the wheel is gone. The ditch covers 30 acres, and when used irrigated 5 acres of alfalfa. This ran 6 tons to the acre per year. Wheat in the same region runs 5 sacks to the acre. The comparison is in favor of the alfalfa. The ditch is one-fourth of a mile long, 18 inches wide, 1 foot deep, and is on a grade of one-fourth inch to the rod. It is under private ownership, and the cost to maintain it is $20 per year. The title to water is based on appropriation and use, and the amount taken is governed by need. Water is found at 16 feet.

DREW DITCH.

Two miles above the head of the Smith Ditch is the head of the Drew Ditch, on the west side of Stony Creek. This ditch, which was constructed in 1896 at a cost of $300, is 1 mile long, 2 feet wide, 1 foot deep, and has a fall of one-fourth inch to the rod. It irrigates 5

acres of alfalfa, from which four crops a year are cut at $1\frac{1}{4}$ tons to the acre per crop. Wheat in the vicinity runs from 700 to 800 pounds per acre. The alfalfa is worth as stock feed $6 per ton, and the higher value of the irrigated crop is again shown. The ditch is under individual ownership and costs for maintenance $25 per year. The title to water is based on appropriation and use and the amount of the claim is based on need. Water is found at a depth of 12 feet.

BAYLOR DITCH.

This ditch heads on the west side of Stony Creek 1 mile above the head of the Smith Ditch. It was constructed in 1886, at a cost of $400, and is 1 mile long, 2 feet wide, and 12 inches deep, with a grade of one-fourth inch to the rod. It irrigates, when used, 20 acres of prune trees, and this orchard has run as high as 17 tons of dried fruit. The ditch is dry this year (1901) and the orchard has no fruit. Indeed, none of the orchards along Stony Creek is bearing this year owing to the late frosts. The ditch is under private ownership, and its maintenance costs $100 a year. The title to water is based on appropriation and use. Water is found at a depth of 20 to 30 feet.

BEDFORD DITCH.

Next is the Bedford Ditch, which heads on the east side of Stony Creek $1\frac{1}{2}$ miles above the head of the Baylor Ditch. It was built in 1877, at a cost of $480, and is three-fourths of a mile long, 18 inches wide, and 8 inches deep. It follows the country grade and irrigates 6 acres. Three acres of this are in alfalfa and the balance is in fruit and garden. The fruit and garden yield could not be obtained. The alfalfa runs $1\frac{1}{2}$ to 2 tons to the cutting per acre and four or five cuttings a year, and is worth as stock feed $5 per ton. The ditch is under private ownership, and its maintenance costs $20 per year. The title is based on appropriation and use, and amount is not defined. Water is found at a depth of 20 to 40 feet.

W. FRIDAY DITCH (GREEN ESTATE).

The next is the Friday Ditch, which heads on the west side of Stony Creek about three-fourths of a mile above the head of the Bedford Ditch. It was built between 1878 and 1880 by Chinese tenants on the S. N. Green estate, and cost $200. It is one-half mile long, 3 feet wide, 12 inches deep, and has a grade of one-fourth inch to the rod. This ditch covers 9 acres of land which is farmed to vegetables, the value of the crop for the 9 acres being about $1,000 annually. Wheat on the same land, unirrigated, yields a return of from $7 to $8 an acre. The ditch is under private ownership, and costs $75 per year to maintain. The title to water is based on a notice posted and recorded in 1884, the filing calling for 288 miner's inches. Surface wa is found at from 20 to 30 feet.

WEST DITCH.

This ditch is an extension of the Friday Ditch, and was constructed by Chinese renters in 1881 at an unknown cost. It is 1 mile long and the cross section of the flumes on this ditch is 12 by 16 inches and the grade one-fourth inch to 100 feet. It irrigates 20 acres of alfalfa, from which four crops per year are cut, at $1\frac{1}{4}$ tons to the acre for each cut. Wheat here runs 650 pounds to the acre. The ditch is owned by two individuals as partners, and costs to maintain $15 per year. The title to water is based on a notice posted and recorded. This filing calls for 144 miner's inches of water. Water and bed rock are found at a depth of from 8 to 10 feet.

GATLIFF DITCH.

The Gatliff Ditch heads on the east side of Stony Creek $2\frac{1}{2}$ miles above the head of the Friday Ditch. It was constructed in 1892, at a cost of $400, and is 2 miles long, 3 feet wide, and 18 inches deep, with a grade of five-eighths inch to 100 feet. It irrigates 50 acres of land, of which 30 acres are in alfalfa and 20 acres in deciduous fruit trees. The alfalfa yields $1\frac{1}{2}$ tons to the cutting per acre and is cut four times a year. The value of the alfalfa is $6 per ton as a stock feed. The orchard, owing to frost conditions, does not yield so good a return, acre for acre, as does the alfalfa. The ditch is owned by an individual, and its maintenance costs $75 per year. The title to water rests on a notice posted and recorded, and the amount claimed is "not less than 400 miner's inches." Water is found at a depth of 18 feet here.

MANSON & ANDERSON DITCH.

This ditch heads on the west side of Stony Creek at a point three-fourths of a mile above the head of the Gatliff Ditch, and was constructed about 1886, at a cost of $750. It is 1 mile long, 4 feet wide, 2 feet deep, and is on a grade of three-eighths inch to the rod. It irrigates 15 acres of land, 10 acres of which are in alfalfa and 5 acres in deciduous fruit trees. The alfalfa is cut four times a year and yields $1\frac{1}{2}$ tons to the acre for each cutting. As stock feed the alfalfa is worth $5 a ton. The orchard returns are very small, owing to frost conditions. The ditch is a partnership affair and the cost to maintain it is $35 per year. The title to water is based on a notice posted and recorded and the filing calls for 200 miner's inches. Water is found at a depth of 20 feet.

WILLIAM TROXELL DITCH.

The Troxell Ditch heads on the west side of Stony Creek at a point 1 mile above the Manson & Anderson Ditch. Information in reference to this ditch was not obtainable.

J. JOHANNSEN DITCH.

The Johannsen Ditch heads on the west side of Stony Creek 1¼ miles above the head of the William Troxell Ditch. It was constructed in 1886, at a cost of $1,000, and is 3 miles long with an average cross section 6 by 2 feet and a grade of one-eighth inch to the rod. It covers from 150 to 175 acres of land and at present irrigates 60 acres of alfalfa. Three crops a year are cut from this, averaging 1½ tons to the acre for each cutting. The alfalfa here has a stock-feeding value of $6 per ton, and the value as compared to unirrigated crops is placed at 6 to 1. The ditch is under private ownership, and its maintenance costs $82.50 a year. The title to water is based on a notice posted and recorded, which calls for 1,000 miner's inches. Water is found at a depth of from 8 to 10 feet.

FRUTO LAND AND WATER COMPANY DITCH.

The head of this ditch is on the east side of Stony Creek, 150 feet below the head of the Johannsen Ditch. It was constructed in 1886, and is 5¼ miles long, with a cross section of 24 by 24 inches and a grade of three-eighths inch to the rod. The water is used for orchard irrigation, but owing to frost conditions the orchards yielded no returns this year (1901). The ditch is owned by a company. Further information in regard to this ditch was not obtainable.

CARVER DITCH.

This ditch heads on the west side of Stony Creek, 2 miles above the head of the Johannsen Ditch. It was constructed in 1883 at a cost of $2,000 and is 1½ miles long, with an average cross section of 3 by 1.5 feet and a grade of 18 inches to the mile. It covers 75 acres of land, but has not been used for two seasons, 1900 and 1901. No figures could be obtained on crops for previous years. The ditch is under private ownership and its maintenance costs $50 per year. The title to water is based on a notice posted and recorded, and the filing calls for 1,200 miner's inches. Water is found at a depth of from 18 to 20 feet.

LORENZ DITCH.

This ditch heads on the east side of Stony Creek, at a point 1¼ miles above the head of the Fruto Ditch. It was constructed in 1880–81 at a cost of $150, and is one-half mile long, 2 feet wide, 1 foot deep, and has a fall in its total length of 1 foot. It irrigates 10 acres of land, which is used for corn growing. The crop is fed to hogs and poultry, and is made to yield a return of about $18 an acre. The ditch is under private ownership and its maintenance costs $20 a year.

The title to the water is based on a notice posted and recorded, and the filing calls for 1,600 miner's inches. Water is found at a depth of 16 feet.

SOETH DITCH.

The Soeth Ditch heads on the east side of Stony Creek 1¾ miles above the head of the Lorenz Ditch. It was constructed in 1882–83 at an approximate cost of $200 and is three-fourths of a mile long, 4 feet wide, 18 inches deep, and has a fall in its total length of 6 feet. It covers 20 acres, of which 10 acres are at present irrigated. The crop is alfalfa, which is cut four times a year and runs 1½ tons to the cut per acre. The alfalfa here has a stock-feeding value of $6 per ton. Wheat in this region runs 1,000 pounds to the acre. The ditch is under private ownership and its maintenance costs $20 a year. The title to water is based on appropriation and use, and the amount taken is governed by the need. Surface water is found at from 16 to 35 feet.

WALKER DITCH.

The Walker Ditch heads on the west side of Stony Creek 2½ miles above the head of the Soeth Ditch. It was constructed in 1881 at a cost of $100, and is 1 mile long, 2 feet wide, 10 inches deep, and has a grade of one-fourth inch to the rod. The ditch covers some 30 acres, of which about 15 acres are irrigated. Nine acres are in alfalfa and the balance is used as garden and orchard for domestic purposes. The alfalfa yields four crops a year at 1½ tons per acre to the crop, and has a stock-feed value of $5.50 a ton. The ditch is a private enterprise, and costs $30 a year for maintenance. The title to the water is based on appropriation and use, and the amount taken is governed by need. Water is found at a depth of 20 feet.

HADDICK DITCH.

The next is the Haddick Ditch, with its head on the west side of Stony Creek, 2 miles above the head of the Walker Ditch. It was constructed in 1895 at a cost of $350, and is 1 mile long, 3 feet wide, 18 inches deep, and has a grade of 3.5 feet in its total length. It covers some 80 acres, but has been unused for the two seasons of 1900 and 1901, and no figures as to previous yield could be obtained. The ditch is under private ownership and its maintenance costs $30 per year. The title to water is based on appropriation and use, and the amount is governed by the need. Water is found at a depth of from 6 to 10 feet.

W. A. McKAIG DITCH.

On the east side of Stony Creek, just across from the Haddick Ditch head, is the head of the McKaig Ditch. This ditch was constructed

in 1890 at a cost of some $250 and is 2 miles long, 4 feet wide, 18 inches deep, and has a grade of one-fourth inch to the rod. It covers 100 acres, of which 30 acres are planted to alfalfa and irrigated. This alfalfa cuts 4 crops to the year, with 1½ tons to the acre per crop and has a stock feed value of $6 per ton. Wheat in the same section runs 1,300 pounds to the acre. The ditch is under private ownership and its maintenance costs $50 a year. The title to water is based on appropriation and use and the amount is dependent on the need. Water is found at a depth of from 20 to 40 feet.

ZUMWALT DITCH.

On the east side of Stony Creek, 1½ miles above the head of the McKaig Ditch, is the head of the Zumwalt Ditch. This ditch was constructed in 1889 at a cost of $625 and is 1¾ miles long, 2 feet wide, 18 inches deep, with a grade three-fourth inch to the rod. It irrigates 50 acres of alfalfa, which is cut four times a year and yields 1½ tons to the cutting per acre. The alfalfa has a stock feeding value here of $6 per ton. Wheat produces 900 to 1,000 pounds per acre. The ditch is under private ownership and its maintenance costs $50 per year. The title to water is based on a notice posted and recorded, but the amount called for in the filing could not be obtained. Water is found at a depth of 20 feet.

JOHN M'DANIEL DITCH.

The McDaniel Ditch heads on the north side of Stony Creek at a point 1½ miles above the head of the Zumwalt Ditch. It was constructed in 1881, at an approximate cost of $100, and is three-fourths of a mile long, 2 feet wide, 8 inches deep, with a grade of one-fourth inch to the rod. It irrigates 30 acres of alfalfa, which is cut four times a year, and runs 1½ tons to the acre for each cutting. This alfalfa has a stock feeding value of $5 per ton. Wheat here runs 1,000 pounds to the acre. The ditch is under private ownership, and its maintenance costs $25 a year. The title is based on appropriation and use, and the amount used is based on the need. Water is found at a depth of 8 feet.

MONTGOMERY DITCH.

The next ditch is the Montgomery, with its head on the east side of Stony Creek, one-half mile above the head of the McDaniel Ditch. It was built in 1897, at a cost of $75, and is one-half mile long, 18 inches wide, 14 inches deep, with a grade of 4 feet to the mile. It irrigates 25 acres of land which is used as a vegetable garden by Chinese renters. Figures as to the value of crops could not be obtained from these renters. The ditch is under private ownership, and its maintenance costs $27.50 per year. The title to water is based

on appropriation and use, and the amount is governed by the need. Water is found at a depth of 6 feet.

BROWN PLACE LOWER DITCH (PUGH DITCH).

Two miles above the head of the Montgomery Ditch, on the north side of Stony Creek, is the head of this ditch. The date of construction and the cost of this ditch were not obtained. It is 1½ miles long, 4 feet wide, 2 feet deep, and has a fall of 1 inch to the rod. It is used to irrigate 150 acres of alfalfa, from which three crops are cut each year, aggregating 4½ tons to the acre. This alfalfa has a feeding value for stock of $6 per ton. The ditch is under private ownership, and the annual cost of maintenance is $75. The title to water is based on a notice posted and recorded, but the amount of this filing is not known. Water is found at a depth of 10 feet.

BROWN PLACE UPPER DITCH (WEBB DITCH).

On the north side of Stony Creek, one-half mile above the head of the Brown Lower Ditch, is the head of the Brown Upper Ditch. The date of construction and the cost of this ditch were not obtained. It is 1 mile long, 4 feet wide, 2 feet deep, and has a grade of 1 inch to the rod. It irrigates 50 acres of alfalfa, which is cut three times a year. The yield is 1 ton to the acre for each cutting, and its feeding value for stock is $6 a ton. The ditch is under private ownership, and costs $50 a year for maintenance. The title to water is based on a notice posted and recorded, but the amount of water claimed in the filing was not obtained. Water is here found at a depth of 11 feet.

STONY CREEK IMPROVEMENT COMPANY DITCH.

Some 2 miles above the head of the Brown Upper Ditch, on the south side of Stony Creek, is the head of the Stony Creek Improvement Company's ditch. The first construction work, costing $300, was done on this ditch in 1865. This original construction work has been added to from time to time, making the actual cost of the ditch and the flumes some $2,500. It is three-fourths of a mile long, 6 feet wide on the bottom, and 10 feet on the top; it is 3 feet deep and has a fall of 5½ feet to the mile. It covers and irrigates 380 acres of alfalfa, from which four crops are cut annually. These crops average 1½ tons to the acre each, and the alfalfa has a feeding value for stock of $8 per ton. Wheat on the same land, unirrigated, runs 700 pounds to the acre, and in many parts it does not even return the seed. The ditch is a corporation affair and is handled by renters, and its maintenance costs $150 a year. The water was appropriated by an individual in 1865, and this right was sold to the present corporation. Water is found at a depth of from 8 to 10 feet. This ditch is one of the most

interesting on the creek, as it shows in a rather large way the value of an intelligently handled alfalfa crop.

HICKOCK & POLLY HEIRS DITCH (BURGETT PLACE).

On the north side of Stony Creek and one-half mile above the Stony Creek Improvement Company's ditch is the head of the above-named ditch. It was constructed in 1887, at a cost of $650, and is 1¾ miles long, 4½ feet wide, 2 feet deep, and has a fall of three-eighths inch to the rod. It irrigates 139 acres of alfalfa, which is cut three times a year. It runs 1½ tons to the acre to the cutting, and has a feeding value for stock of $5 a ton. The ditch is under private ownership and costs for maintenance $70 a year. The title to water is based upon a notice posted and recorded in the name of H. Burgett. The amount of water called for in the filing is 1,152 miner's inches. Water is found at a depth of 8 feet here.

WILLIAM MORRIS DITCH.

One-fourth of a mile up Stony Creek from the head of the Hickock Ditch and on the north side of the creek is the head of the William Morris Ditch. This ditch was constructed in 1884 at a cost of $10. It is one-fourth of a mile long, 12 inches wide, and 10 inches deep, and has a fall of 7 feet to the mile. The ditch is not in use this year. It was formerly used to irrigate 6 acres of vegetable garden. No figures on the product are obtainable. The ditch is under private ownership and costs $5 a year to maintain. The title to water rests on appropriation and use, and the amount is governed by need. Water is found at a depth of about 20 feet.

MORRIS & WELTON DITCH.

This ditch heads on the south side of Stony Creek five-eighths of a mile above the head of Stony Creek Improvement Company's ditch. It was constructed in 1870, at a cost of $1,750, and is seven-eighths of a mile long, with an average cross section of 3.5 feet and a grade of three-eighths of an inch to the rod. It covers 100 acres, of which 35 acres are irrigated. Thirty-three acres are planted to alfalfa and the balance is orchard for domestic use. The alfalfa is cut four times a year, runs 1¼ tons per acre to the cutting, and has a stock-feeding value of $6 per ton. Wheat on the same land produces 400 pounds to the acre. The ditch is owned in partnership by two individuals and costs about $60 for maintenance per year. The title to water is based on appropriation and use and the amount is governed by need. Water is found at a depth of 23 feet.

FRED LOUX DITCH.

This ditch was built in 1876, at a cost of $500. The ditch is between three-fourths and 1 mile long, is 2½ to 3 feet deep, and built on a

grade of 1½ inches to the rod. The head of the ditch is on the north side of Stony Creek, about one-half mile above the head of the William Morris Ditch. The water is used to irrigate about 10 acres of land, 9 acres of which are in alfalfa and the balance in garden truck. The annual yield is from 4 to 5 tons per acre of alfalfa, with a value for feeding purposes of about $6 per ton. For a title a notice was posted and filed with the county recorder of Colusa County in the name of Deboben. The ditch is all under private ownership and costs from $50 to $75 per year to keep in proper order. Water is found here at a depth of 16 feet.

J. R. DAVIS & BRO. DITCH.

This ditch was built in 1898, at a cost of $105, the length being about 1 mile, with a fall of 1½ inches to the rod, 12 inches deep, and from 12 to 18 inches wide. The head is situated on the west bank of Middle Fork of Stony Creek, about one-half mile below Fouts Springs bath house. At present about 10 acres are irrigated from this ditch, 4 acres of which are in alfalfa; the balance is in corn, garden truck, and fruit trees. The alfalfa yields about 1½ tons to the acre at each cutting and four cuttings are usually made during the season. The product is fed to stock. A notice was posted, filed, and recorded in the name of J. W. Shinks, in the county of Colusa. About $40 a year is expended on the ditch.

FOUTS SPRINGS MILL CREEK DITCH.

This ditch was built in 1896, at a cost of $300. The ditch is one-half mile long, 18 inches wide, and 18 inches deep, with a fall of one-half inch to the rod. The head is on the east side of Mill Creek, one-half mile from Fouts Springs Hotel. The ditch is capable of irrigating 2 acres of land, which is usually put down to garden truck, to be used at the hotel, and the value of the crop is $50 per acre. Title to water rests in appropriation and use. The ditch is under private ownership and its maintenance costs about $10 per year. This is the only ditch on Mill Creek. The depth to water here is 6 feet.

FOUTS SPRINGS DITCH.

This ditch was built in 1881, at a cost of $3,000. The length is 2 miles, with a fall of one-half inch to the rod, with the exception of one place, where there is a drop of 100 feet. The head is on the south side of South Fork of Stony Creek, 2½ miles from Fouts Springs Hotel. The water is all used for domestic purposes. Owing to the porous nature of the soil, only about one-tenth of the water at the head ever reaches the end of the ditch. The title to the water rests on the appropriation and use of it. The ditch is under private ownership and costs about $100 per year for maintenance. The hotel is used as a summer resort, people coming here to drink the water from numerous

mineral springs about this section of the country. This is the last ditch on Stony Creek.

These more or less complete returns from 37 ditches show an average value for alfalfa, the cheapest and most easily handled irrigated crop, of $32 per acre, gross. The wheat yield on the same land, as a typical unirrigated crop, may be placed at $7.50 per acre. As for fruit yields, we can give no comparative figures, as the crop this year was ruined by the spring frosts. With sufficient water the whole region considered would carry alfalfa, and might be the fattening ground for great herds of beef cattle, thus giving the best and surest returns. As for the fruit raising, it is no longer an experiment on the plains, and there are many hundreds of acres of good orchard land that merely need water to make them productive. The sparsity of population in the unirrigated sections is noticeable, and the distance between schoolhouses is great. This is in marked contrast to the conditions prevailing in the irrigated sections.

STORAGE DAMS.

A notable case of the utilization of storm waters is to be seen on the Griffith estate, which is located on the Alder Flats road about 5 miles from the town of Elk Creek. The party working this estate, Mr. Gould, has placed a high dam at the confluence of two gullies on the upper part of the ranch. This dam is built of the natural earth from the surrounding hills. It was built in 1898, and cost $600. When the impounding space is full the water covers from 20 to 25 acres of what would otherwise be waste land. This water is enough to irrigate 25 acres of alfalfa, from which three or four crops are cut annually. The alfalfa runs 1½ tons per acre to the cutting, and previous to the use of water upon it the land was of use as a spring pasture only. The water impounded comes from the surrounding hills in the winter, and the reservoir formed by the dam is easily filled each year; in fact, a much larger space might be filled were the surplus water not allowed to waste.

The same thing might be done on a large number of ranches where water for irrigation would otherwise be unobtainable. There can be no question that such work as this pays well.

CENTRAL IRRIGATION CANAL.

Crossing Stony Creek at about 4 miles from its mouth are to be seen the remains of one of the largest irrigation canals in the State, and while this particular canal did not take its water from the creek in question, it furnishes an object lesson in trying to do too much and failing that it deserves mention. The canal was begun as a district enterprise under the Wright law in 1887. It was intended to take water from the Sacramento River at a point 7 miles above the mouth of Stony Creek and was to cover a vast area of land. The canal as projected and partly built was to have a width on the bottom of 80

feet, 120 feet on top, and an average depth of 14 feet. The contract price for the excavation was $700,000. The crossing of Stony Creek was made in a set of cylindrical wooden conduits buried beneath the gravel bed of the creek. These conduits were 650 feet long, and at both ends of them elaborate masonry and timber gates were placed to restrain the canal waters and keep out the winter high waters of Stony Creek. The cost of this crossing work was $78,000. The floods of the past winters have so weakened the uncared-for conduits over Stony Creek that it has been found necessary to remove them, at heavy expense, to save certain bridges down the creek from the destruction sure to follow were they to break away entirely. The old canal serves as a reservoir for the seepage water of the whole region through which it passes, and makes a pretty picture, though in reality it serves as a breeding place for hordes of mosquitoes, and is considered a source of much ill health in its vicinity. Plans for the completion of this canal are now being worked out, and the irrigation of the district it covers in the near future seems to be assured.

Gagings were taken on all the ditches in which water was flowing, and the results are to be found in the accompanying table. The amount of water wasted is noticeable. This waste is due to seepage in a large degree, and is especially noticeable in the first few hundred feet of ditches where they pass through gravel.

Discharge of Stony Creek ditches, 1901.

Name of ditch.	Where measured.	Date.	Discharge.
			Cu. ft. per sec.
Stony Creek Irrigation Co	At head	July 9	13.32
Do	At Mrs. Hall's	do	7.19
Do	Opposite Murdock ranch, at foot-bridge.	do	7.00
Do	At head gate, alfalfa field near schoolhouse.	do	6.65
Do	At first ford	do	5.95
Reed Lateral, Stony Creek Irrigation Co.	At head	do	.42
Hall & Scarce	do	do	1.51
Do	At orchard fence	do	1.36
Miller (Chinese)		July 22	2.76
Chinese garden	On Julian ranch	July 19	.53
Drew	At head	July 13	3.96
Bedford	do	July 14	1.02
West extension of Friday Ditch	At cemetery	do	.34
Friday, or Green Estate		July 18	.53
Rowlings	At head	July 15	1.37
Manson & Anderson	do	do	1.38
William Troxell	Near head	do	.35
J. Johannsen	At head	do	2.21
Fruto Land and Water Co	do	do	1.93
Lorenz	Near head	do	.46
Soeth	At head	do	1.04
Walker	do	do	.47
McKaig	do	do	3.26
Zumwalt	At flume	do	.66
McDaniel		do	2.63
Montgomery		July 18	.48
Brown No. 2		do	3.65
Brown No. 1		do	3.03
Stony Creek Improvement Co		July 17	7.98
Hickock	At head	do	16.85
Morris & Welton	do	do	2.36
Loux	do	do	3.74
Davis		do	.34
Fouts Springs, south fork		July 16	.97

IRRIGATION IN THE BLACK HILLS, SOUTH DAKOTA.

A. B. Crane, *Agent and Expert.*

INTRODUCTION.

The Black Hills are isolated from any general mountain range and form by themselves a miniature mountain system, which offers an interesting field for the investigator.

Numerous small streams have their sources in these hills. They rise from springs and are augmented by the melting snows which lodge in the valleys and gulches in winter. These streams flow through steep and rocky canyons radiating to the north, east, and south till, cutting through the outer rampart of foothills, each stream spreads out into a fine valley, finally emptying into one of the forks of the Cheyenne River, the two branches of which encircle the hills and separate them from the surrounding prairie.

These valleys are all fertile and become very productive when supplied with water, although quite barren and devoid of vegetation when not irrigated. The majority of the first settlers in these valleys came from Montana and, being acquainted with the use and value of water, located with reference to a water supply, filing their water rights almost as soon as they took out their land claims, many of them as early as 1876 and 1877. Thus we see that as an agricultural district, the Black Hills country is the oldest part of South Dakota, except a small section on the eastern border near the Iowa and Minnesota line. It is also a most prosperous district, made so by means of irrigation.

SPEARFISH CREEK VALLEY.

Of these hill streams, the one on which irrigation has been carried on most systematically is Spearfish Creek, which rises in two big springs near the southern boundary of Lawrence County and, flowing northward, is augmented by a few tributaries, Little Spearfish Creek being the largest. This valley is typical of all the others and a detailed account of methods and results given will apply to the other irrigable valleys of the Black Hills district.

Spearfish Creek is uniform in its flow, the fluctuations at different seasons being remarkably small. It has a fall through its canyon of about 100 feet to the mile, which gradually lessens farther down the valley, the average fall there being about 60 feet to the mile. It carried on

August 21, 1902, at the time of the measurement, 49.1 cubic feet per second, an equivalent of 1,964 Montana miner's inches. The stream at the mouth of the canyon above all irrigation ditches was 36 feet wide, averaged 0.77 foot deep and flowed with an average velocity of 1.14 feet per second. The discharge as given above was more accurately measured at the flume of the electric light power house three miles farther up the stream. A single measurement of a stream gives a very slight idea of the discharge. At the time of these investigations the flow was approximately at a minimum.

There are twelve ditches taken out of the creek for irrigation purposes, besides four for power. These power ditches empty back into the creek and divert no water for the purposes of irrigation. The Home-Stake Mining Company, however, has installed a pump above the canyon, about 20 miles above the valley, from which they pump water to their mines at Lead City. Though they claim to draw from an underflow, it is thought that what they take lessens the supply for the valley, as it is not returned to the Spearfish, but flows off through Deadwood and Whitewood creeks. The mining company's claim, as near as could be ascertained, is for 400 miner's inches, an equivalent of 10 cubic feet per second. Regarding its effect upon the valley itself, there is an abundance of water, if properly distributed, to irrigate all the land.

OWNERSHIP AND CAPACITY OF DITCHES.

The following tabular statement gives the names of the ditches, beginning at the canyon and proceeding down the stream; also the year they were taken out, the amount claimed, the amount actually flowing at the time of this investigation, the length of the main ditch, and the number of acres irrigated by each, as ascertained by interviews with the different ditch owners.

The books containing the early water-right records were burned in a fire which destroyed the city of Deadwood in 1879, and no maps could be found which showed the location of these ditches. The table given is based upon the statements of the owners of ditches and other old settlers in the valley. As near as can be ascertained the figures here given are correct. The flow is reduced to Montana statutory miner's inches, as that is the method of measurement in common use in this valley. The tabular statement is as follows:

Appropriations claimed, dimensions, and capacities of the irrigation ditches of Spearfish Valley, South Dakota, August 21–30, 1902.

Ditch No.	Name of ditch.	When constructed.	Volume of water claimed.	Volume of water carried.	Equivalent in miner's inches.	Length.	Area irrigated.
			Miner's inches.	*Cu. ft. per second.*	*Miner's inches.*	*Miles.*	*Acres.*
1	Gregg & Mathews	1878	400	4.407	176.28	2	150
2	Mathews & Son	1877	750	15.005	600.20	1½	250
3	Walton & Co	1877	400	10.649	425.96	3½	450
4	Mann	1877	350	1.984	79.36	2	80
5	Fred Ackles	1877	400	5.904	236.16	3	190
6	Evans & Co	1876	2,500	19.263	770.52	2½	800
7	J. E. Cook & Co	1878	2,500	7.192	287.68	2½	1,320
8	Wm. Smith & Co	1877	2,500	3.560	142.40	1½	200
9	Parsons & Cogal	1897	200	.874	34.96	1¼	40
10	Wm. Cook & Co	1877	5,000	4.240	169.60	3	670
11	Kemper & Dorset	1877	5,000	11.400	456.00	2	300
12	Bowman & Co	1878	400	6.990	279.60	1½	360
	Total	....	20,400	91.468	3,658.72	26¼	4,810

In addition to these, there are three other ditches which, though not drawing their supply directly from Spearfish Creek, belong to this system, as they are supplied from one of its tributaries. Higgins Gulch, rising on the eastern slope of Crow Peak, flows in a northeasterly direction toward the Spearfish. As it passes through the sandstone formation forming the outer rim of the hills it disappears; reappearing a few miles farther on in several large springs. One ditch is taken out before the stream disappears and two after its reappearance. These last two ditches irrigate ranches in the valley, while the first is in a tributary valley. A tabular statement of data regarding these ditches is as follows:

Ditches on Higgins Gulch and Spring Creek, Spearfish Valley, August 21–30, 1902.

Ditch No.	Name of ditch.	When constructed.	Volume of water claimed.	Volume of water carried.	Equivalent in miner's inches.	Length.	Area irrigated.
			Miner's inches.	*Cu. ft. per second.*	*Miner's inches.*	*Miles.*	*Acres.*
1	Wells	1877	100	1.028	41.12	1½	100
2	Toomey	1877	300	4.203	168.12	1¼	225
3	Lindley	1876	300	5.094	203.76	1¼	200
	Total	....	700	10.325	413.00	4	525

This tabular statement shows:

First, the quantity of water claimed from Spearfish Creek by appropriators is about six times the flow of the stream at the time of measurement.

Second, the total volume carried by all the ditches is 1.86 times the volume flowing in the stream above all the ditches.

Third, there are 5,335 acres irrigated with 4,071.72 miner's inches of water, or about 1.31 acres per miner's inch at the time of minimum supply. This acreage could be greatly increased by a careful use of the supply, as at present very little pains is taken to prevent waste.

The ditches are all owned by the people using the water and not by corporations who sell to the users. Each man's thought is to have what he needs and let the balance go by for whoever wants it. This, in the main, is satisfactory, for there is usually an ample supply for all, though occasionally an agreement has to be made among the parties as to the time when each shall be allowed the full use of the ditch, alternating with the others until all are supplied. As a result, little litigation has arisen between the owners, dissensions being settled amicably between themselves.

When water is scarce the ditches along the middle of the valley, such as Nos. 7 or 8, feel the effects first. This is probably due to the fact that the seepage from the upper ditches does not reach the creek until it gets beyond the heads of these ditches. When it reaches the stream it affords a supply for the ditches lower down.

A measurement of the creek at its mouth and below all the ditches shows a flow of 1,308.16 miner's inches. This shows to what an extent seepage from the upper ditches back into the stream goes on, thus letting the water become available perhaps several times in its course through the irrigable district.

METHODS OF IRRIGATION.

No storage reservoirs or lifting apparatus are used. The means adopted for taking the water from the stream is to construct a slight dam of brush, stones, and earth, which raises the water 2 or 3 feet above its normal height, and sufficient to divert the quantity needed into the head gate just above the dam. The usual fall of these ditches is one quarter of an inch to the rod. Sometimes flumes have to be built across depressions, sometimes a cut has to be made to carry it across a divide, but usually the ditch lies near the natural surface, and can be tapped at almost any point in its entire length. The soil being a tenacious clay, does not absorb excessively, but allows almost the entire flow to pass on to its destination. From these ditches it is carried by laterals directly to the land to be irrigated, and is there used either by flooding or furrows, to suit the convenience of the irrigator and the crop to be irrigated. Any surplus water and seepage is naturally drained back into the creek and is carried on to the next ditch.

The formal method of appropriating water from the stream was by filing a certificate of appropriation with the register of deeds, posting a copy of this certificate near the head of the ditch, and beginning operations on the ditch within a specified time. The certificate contains the names of the appropriators, the date of appropriation, the point from which it is taken, and the place it is to be used. Most of the ditches in the Spearfish Valley were taken out between 1876 and 1878, while the earliest laws regarding water rights seem to be those passed in 1881. The early form of appropriation was in the

main in conformity with the statutes as adopted at that time. (See Compiled Laws of South Dakota, Political Code, sec. 2031 et seq.)

COST AND EXPENSES.

The cost of building these ditches is variously estimated at from 25 to 50 cents per rod, depending on the local conditions, amount of fluming, etc., though a close estimate is hard to form, owing to the fact that they were built so long ago and under very disadvantageous conditions as to help, tools, etc. The expense of cleaning and maintaining them is about $25 per year for each quarter section, or, as some have apportioned it, 20 cents per acre for each acre under the ditch.

Ditches are maintained as follows: A superintendent is selected by the owners, usually from their own number. When work is to be done this superintendent notifies the others and each comes out and does his proportional part of the work, or if for any reason he can not come, he is assessed his proportional part and a man hired in his stead. The proportion is made on the basis of acreage which each has under the ditch. Each man has to maintain and look after his own laterals as individual property. In the fall of the year, just before it freezes, all the head gates are closed tightly for the winter. This leaves the ditches dry, and thus prevents cracking and other injury from ice. In the spring, about April 1, the superintendent calls out the owners and the ditch is thoroughly cleaned and repaired from head gate to terminus and made ready for the water.

APPLICATION OF WATER.

Irrigators have different methods of applying the water. Some prefer to flood the ground the last thing in the fall, allowing it to freeze wet. Others apply no water after the middle of August until the crop in the spring seems to need it. Each man is "a law unto himself." Those raising alfalfa and other hay crops wet the soil as soon as each crop is taken off the field, except after the last crop, when the ground is left dry to prevent the heaving of the roots and winterkilling. Those raising trees and shrubbery use no water after the middle of August, thus giving the wood opportunity to mature and so prevent winterkilling, but turn on the water again just before winter, thus letting the ground freeze wet. Mr. Joseph Wells, who has the most successful apple orchard in the valley, floods his orchard but once during the year—about the last of June—just after taking off his first crop of clover hay from the ground. He raises two crops of clover each year in his orchard.

Care is taken in applying water not to let it wash gulleys and furrows in the soil.

In estimating the amount of water needed it is usual in this valley to figure on 1 miner's inch to the acre, though the duty of water

varies with the extent of the irrigated area. In a small 5-acre field this is found to be hardly sufficient, while on the large ranches of several hundred acres devoted to hay it is found that 100 miner's inches will irrigate 200 acres.

SIZE OF FARMS.

In the upper end of the valley near the city of Spearfish the large farms have been divided up into small 5, 10, and 15-acre holdings. These have been set out to small fruits, orchards, and gardens, and each is capable of supporting a family. Thus where before there was but one family on a quarter section there are now six or eight well-kept homes, thrifty groves, and luxuriant gardens. The appearances of comfort, thrift, and prosperity speak well for "the small farm, well tilled," as a means of an independent, comfortable livelihood. This condition is gradually extending down the valley, each farm being divided up into smaller areas and put on the market as soon as the preceding one is disposed of.

NATURE OF CROPS.

At first considerable grain was raised and the yield was good, wheat going from 25 to 40 bushels to the acre and oats 40 to 60 bushels. But in these small valleys enough could not be raised to give employment to a mill, so it had to be shipped and compete with the wheat of the world. Owing to the distance from market, wheat raising was not found profitable, and the lands were gradually given over to hay meadows, such as timothy and clover and alfalfa. The local demand of the mining cities in the hills and the winter feeding of stock from off the surrounding ranges afforded a ready home market for the entire crop at a profitable figure. The smaller fruit and vegetable farms, however, yield by far the largest returns, though demanding a much greater amount of labor. The yields of the different products have been reported as follows:

Yields of products on irrigated farms, Spearfish Valley, Black Hills, South Dakota.

Crop.	Yield per acre.	Approximate price.
Alfalfa (3 cuttings)	$3\frac{1}{2}$ to 6 tons	$9 to $10 per ton.
Timothy and clover (2 cuttings)	3 to 4 tons	$10 to $12 per ton.
Wheat (very little raised)	25 to 40 bushels	Market.
Oats (very little raised)	40 to 60 bushels	Do.
Potatoes	300 to 500 bushels	$1 to $1.50 per cwt.
Onions	400 to 500 bushels	Do.
Apples	25 to 30 barrels	$4 per barrel.
Carrots, beets, turnips, etc	20 to 30 tons	
Strawberries	3,500 to 5,000 quarts	20 cents per quart.
Raspberries	3,000 to 4,000 quarts	Do.
Blackberries	2,000 to 3,000 quarts	Do.
Dewberries	3,000 to 4,000 quarts	Do.
Gooseberries	do	Do.
Currants	4,000 to 5,000 quarts	Do.

These are the main market crops, but radishes, asparagus, peas, beans, and all other garden vegetables are raised in great profusion. This is a remarkably fine showing. It seems to further indicate that the Black Hills region is the natural home for the small fruits.

Questions were asked regarding the comparative advantages of farming under irrigation and under rainfall. With but one exception those interrogated expressed themselves as favoring irrigation. They gave as a reason that they preferred to control the time and the amount of water which was applied to their crops, watering when needed rather than depending on rain with its possible vicissitudes. The only natural drawback in the hills country is hail. Hailstorms are frequent and severe, but usually extend only over a very limited area.

PRECIPITATION.

The rainfall in the hills is somewhat greater than on the surrounding plains, being reported as averaging over 25 inches per annum for a great number of years. The records of the Spearfish Normal School for the last five years show a precipitation as follows:

Precipitation at Spearfish, S. Dak., 1897–1901.

Year.	Precipitation.	Year.	Precipitation.
	Inches.		*Inches.*
1897	18.92	1900	17.73
1898	11.89	1901	19.14
1899	17.54		

This is nearly equal to the rainfall in the extreme eastern portion of the State, where agriculture is carried on without irrigation, the average there being about 20 inches per annum. In the Hills country the ground is so sloping and the soil so heavy that this rainfall quickly finds its way into the gullies and creeks and does not wet the soil, except where it is cultivated and under the ditch. Rainfall is not considered as a factor in farming except as a destructive element, spoiling the hay and interfering with farm operations. Its absence is much more welcome than its advent.

VALUE OF IRRIGATED LAND.

The value of these irrigated lands is set quite high. Land that is not capable of irrigation can scarcely find a buyer at $5 per acre, that under ditch brings $100 to $500 per acre, according to improvements in the way of orchards, shrubbery, etc. The smaller farms command the higher price and seem to be the most ready sellers.

OTHER STREAMS OF THE BLACK HILLS REGION.

REDWATER CREEK.

Spearfish Creek empties into the Redwater Creek. The same irrigation system extends on down the Redwater Valley, and the same plan is followed both up and down that stream from the mouth of the Spearfish. The ranches are on a large scale, however, and are devoted almost exclusively to hay, which is fed to range stock during the winter.

Lower down the Redwater Valley, and extending over to the Belle Fourche Valley, is the largest irrigation system in the Hills country. The ditch belongs to the Redwater Land and Canal Company, an English corporation, which claims 4,000 miner's inches from Redwater Creek. The company maintains the ditch and sells water to irrigators of the land which lies under it. This ditch is taken out about 5 miles above the mouth of Redwater Creek. Its entire length is about 42 miles, but the last 12 miles have been abandoned, leaving about 30 miles in use. About 10,000 acres are capable of being irrigated, though only about 5,000 acres are now irrigated. Water is sold to farmers at $1.50 per miner's inch per year, or for small garden patches at $1.50 per acre irrigated. Sixty-three customers were supplied this year (1902). The amount is regulated and measured by weirs at the head gates of the laterals.

The cost of irrigating, in addition to the water rent, is about 50 cents per acre. As large tracts use less than an inch to the acre, a fair estimate of the total cost would be $1.50 per acre. The cost of keeping up this ditch is about $600 per year. Each individual maintains his own laterals.

This company has had no litigation as yet, but there is liable to be controversy with those taking out water above them.

STORM-WATER IRRIGATION.

Redwater Ditch is the last on the river, but there is some irrigation by means of small storage reservoirs. These smaller irrigation schemes are worthy of notice because of their universality of application. They consist of damming one of the many gulches which come from the hills and are filled with water in time of rain or the melting of the winter snows. This backing up of the water forms a reservoir, which when full feeds into a ditch which carries it out upon the land. In this manner, when it rains the water from an extensive area is carried upon and irrigates smaller areas, a reserve supply being left in the reservoir for future use. This method is not as efficient as supplying water when it is needed, but it furnishes a partial supply which, if carefully and intelligently utilized, has been found to produce good crops where there would have been nothing without it.

Mr. Hans Sorenson, on Owl Creek near Snoma, reports that he irrigates 125 acres in this manner, and that this year (1902) he raised 225 tons of good hay. The cost of his dam and ditches was about $1,200. His hay this year is worth $2,250. Without irrigation he would have had nothing. Mr. Sorenson reports that the expense of the plant and of keeping the dams in place is quite large. Several other farmers in this vicinity are irrigating in this manner from 100 to 200 acres. There are hundreds of places in the hills where this method could be employed with good results and a 20 or 30 acre field made to yield a greater income than the whole ranch without water.

Above the mouth of the Spearfish there are two other irrigated valleys in South Dakota tributary to Redwater Creek. These are Chicken Creek and Crow Creek, which irrigate several small ranches.

FALL RIVER VALLEY.

Rapid Creek and Fall River valleys are each representative of a different method of farming. Rapid Creek Valley is given over mostly to hay, the holdings containing several hundred acres each. In contrast to this, Fall River Valley, especially the upper portion, near the city of Hot Springs, is divided into small areas and devoted to fruits and market gardens. The proximity to good local markets makes horticulture as profitable here as in the Spearfish Valley. In addition, the water of Fall River is quite warm (not even freezing during the winter), owing to the many warm springs which flow into it. It tempers the climate of the valley and forces an early and luxuriant growth of vegetation. The G. M. Trimmer orchard of about 5 acres bears about 1,000 bushels of apples, besides pears, plums, and cherries. Mr. Trimmer is also starting a vineyard. This valley is less than half a mile wide and about 6 miles long.

The water for the ditch owned by Mr. J. P. Billups, about 1½ miles below Hot Springs, is raised by means of a huge water wheel, 36 feet in diameter, propelled by the stream, and carrying a system of buckets on its rim. These empty into a flume, which carries the water to the ditch on the upper side of the valley. By means of this wheel Mr. Billups raises 8.4 inches a height of 32 feet and irrigates a tract of 10 acres. Another smaller wheel, made on the same principle, elevates water about 9 feet and irrigates a garden patch of 4 or 5 acres near the upper end of the city, at the Evans plunge bath. There are several other lifting wheels in this valley which have materially widened the irrigable strip.

The price per acre of irrigated land in this valley is estimated to be from $25 to $75, according to the extent to which orchards and small fruits are planted. Land not under ditch, but which might be irrigated, is worth about $10 per acre, while that which is incapable of

being irrigated brings from $1.25 to $5 per acre. Those who rent water from ditch owners pay from $1.50 to $2.50 per miner's inch.

On September 6, 1902, Fall River carried 31.9 cubic feet per second, or an equivalent of 1,276 miner's inches, which is a bountiful supply for all the land capable of being brought under the ditches. There have been no suits over water rights in this valley.

CASCADE CREEK VALLEY.

Cascade Creek lies about 10 miles southwest of Fall River. It does not freeze in winter, being fed by warm springs which temper the natural climate of the valley. A company called the Hot Springs Irrigation and Live Stock Company has been organized for the purpose of utilizing the water from this creek. They intend to carry all the water down Cascade Valley out on the valley of the Cheyenne River. Their ditch is about 13 miles long and is intended to irrigate about 1,500 acres. The price of land in this valley is about the same as in Fall River Valley for the same degree of development.

RAPID CREEK VALLEY.

The irrigable portion of Rapid Creek Valley begins about 6 miles above Rapid City, where the stream breaks through the hills. At this point a dam has been constructed which backs the water up into the canyon, forming a reservoir called Canyon Lake. Only 75 acres are irrigated above this dam. Below Canyon Lake the canyon widens out into a valley from 1 to 2 miles wide, extending on for about 36 miles to its junction with the South Fork of the Cheyenne River. This fine valley is practically all under ditch. Eight ditches were located; some are quite large, carrying 3,000 inches of water. The stream was measured September 2, 1902, at a point about 3 miles above the city, and carried 41.4 cubic feet per second, the equivalent of 1,656 miner's inches. The valley is so extensive that the water supply is not equal to the demand. There have been more suits over water rights in this valley than any other in the hills. The courts have held that priority of appropriation gives a prior right to water; but it is conceded that if land has been taken with reference to the use of the water, the person so taking the land has a riparian right to the use of as much of the water not previously appropriated as is needed for said tract of land.

The water from this stream ought to be used with care and economy, as this is perhaps the largest and best valley in the hills. The flow of the creek fluctuates considerably, and if the spring floods could be stored in reservoirs it would add materially to the available supply.

Mechanical means have been resorted to in several instances for raising water and carrying it upon land which could not be reached by gravity. A water wheel was noted, constructed from two wagon wheels fastened together by boards nailed to the spokes for paddles.

The sides were made tight with shingles. This wheel was fastened to a shaft taken from some old piece of machinery and worked by the water flowing in the irrigation ditch. To the outer end of the shaft was attached a pulley over which ran a canvas belt fitted with galvanized-iron buckets, which were carried over another pulley about 8 feet higher than the stream and there emptied into a box at the head of a flume, from whence it was conveyed to the land, several hundred yards away. Mr. Freeman Lewis, its owner, says it is very effective. A pump run by a water wheel is also in operation in the creek, while Mr. George Sanders raises water by means of a gas engine.

Aside from its value for irrigation purposes, Rapid Creek is especially valuable for its water power. The city electric-light plant and a flour mill are run by the stream. There is power for other enterprises.

BEAVER CREEK VALLEY.

Beaver Creek carries a large flow during the spring and early summer months, but runs nearly dry later in the season. This creek illustrates the best of any investigated the need of some system of storage. At the time of measurement, September 3, 1902, there was a flow of 11.48 cubic feet per second, or 459.2 miner's inches, which is about the minimum flow of the stream. The valley is about 10 miles long, and gradually widens from the canyon to about 5 or 6 miles wide at the mouth. Six or more ditches take water from this stream, but only three are of much importance, as the supply is not sufficient for all. Ten thousand acres in this valley and Cheyenne Valley could be irrigated if the water which goes to waste in the spring could be stored till needed, and there are sites in the hills which could be made into reservoirs in which to store it.

The valley is given over to hay meadows, though some corn and sorghum are raised for feed. There are a few orchards started and farm gardens are thrifty, though no market gardening is carried on.

OTHER STREAMS.

False Bottom, Whitewood, Bear Butte, Alkali, Elk, Box Elder, Spring, French, and Battle creeks flow from the hills on the north and east, but there is very little irrigation from them. In the interior of the hills, owing to the broken nature of the ground and the use of the water for mining purposes, there is no irrigation except an occasional small garden patch.

Whitewood Creek has a good volume, but carries the silt and washings from the mills at Deadwood and Lead City and is unfit for use. The other streams pass over a sandstone strata before leaving the hills and the water sinks. Little goes out into the valley except in time of spring floods. The volume of water coming down at that time is so great as to wash out many diversion dams which have been constructed, so that such attempts have been abandoned.

There are many hundred acres in these valleys which could be irrigated if water could be either stored or prevented from sinking into the ground before reaching the valley. These difficulties are by no means insurmountable, and may possibly be disposed of to the satisfaction of the settlers and the improvement of the country.

IRRIGATION LAWS.

The laws of South Dakota provide that the right to water for irrigation is established by appropriation. There have been a few lawsuits over the matter, but perhaps the best legal interpretation of the law can be found in the two cases Sturr *v.* Beck and Scott *v.* Toomey. The first was tried in 1890, the other in 1896. In each priority of appropriation was accepted as the basis of the right; also in the first case it was held that a riparian right must be respected and held as a prior right if it be such. If the appropriation is made and ditches run through Government land and this land subsequently taken, it must be taken subject to this priority of appropriation and can not interfere with it. This decision is rendered in the case of Scott *v.* Toomey. These two cases are the most important that have been tried in this part of the hills. The decisions rendered in cases occurring in the Rapid Creek Valley have conformed to the interpretations rendered in these cases. (See Sturr *v.* Beck, 133 U. S., 541; also Scott *v.* Toomey, 8 S. D., 639.)

DRY FARMING.

Attempts have been made in several locations to raise crops without irrigation, but it is only once in several years that the conditions are such as to give satisfactory results. The present year (1902) was an exceptionally wet season in the hills, and small crops were raised without irrigation in the Centennial Valley, about 10 miles east of Spearfish, and in some of the parks north of Hot Springs. There is no surety of a crop, however, and many who in earlier days attempted to farm without being able to irrigate have abandoned it and use the unirrigated land wholly for grazing purposes.

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RICE IRRIGATION IN LOUISIANA AND TEXAS, 1902.

By Frank Bond.

The abnormal weather conditions which prevailed in the Louisiana and Texas rice district during the season of 1901 continued through the season of 1902. The fears of the rice growers that they were to suffer not only a repetition of the experience of the past season but also an increase of the influences which then made for a short crop, were fully realized before the pumping season was fairly under way. The presence of salt water in the pumps in many localities on July 15, 1901, led the planters to put their crops in much earlier in 1902, in the hope that should the drought continue, the rice would be matured before the supply of fresh water should give out. This plan of early seeding was generally followed. Climatic conditions favored this experiment; the rainfall during the late fall and winter was so light that plowing, discing, and harrowing were pushed much more rapidly and with less interruption than the average winter would permit, so that seeding began on March 15, an unprecedently early date. Infrequent and light rains permitted the seeding to be done rapidly, and before the 1st of May much rice was in need of water.

THE LESSON OF EARLY SEEDING.

The result of early seeding was not wholly satisfactory, owing in part to the continued droughty condition. Had copious rains fallen between April 15 and June 15 the early rice would, in all probability, have matured sooner than it did. The cool weather of early spring also retarded growth greatly, since rice needs both a uniform and high temperature as well as humidity to insure rapid and healthy growth. March planting followed by normal showers in April and May will undoubtedly insure an earlier harvest than will occur when seeding is postponed to May, June, or July, and all who suffer from lack of fresh water or the invasion of salt water into the bayous during the later summer months will be able to mature and harvest at least a portion of their crops. In the season just closed many farmers under the large canals harvested a fair crop from fields planted in March, while much of the seed planted during May and June did not mature sufficiently to warrant the expense of reaping and thrashing. When the salt water was used on the fields of early planted rice in July the plants seemed to have matured sufficiently to resist, in an appreciable degree, the deadly effect of the brine.

EXPERIENCE ALONG THE MERMENTAU.

Early planting along the Mermentau River and its tributaries necessitated earlier pumping because of the prevailing droughty conditions, and the fresh water was rapidly withdrawn from the stream. It is certain that the supply of fresh water in the upper reaches of these streams was no greater on May 1, 1902, than it was on June 1, 1901. In other parts of the district the fresh-water supply lasted longer than in the latter year, but this was due to opportune local rains which reduced the number of pumps kept at work. Samples of water taken from the Mermentau River at the Pacific Railroad bridge on April 25 showed no appreciable quantity of salt. The river was 40 feet deep, and the samples were taken at a depth of 20 feet and at the bottom. No samples of water were taken below the railroad bridge, but there can be little doubt that salt water occupied the lower reaches of the stream at that time, as is shown by the rapidity with which salt water rushed into the upper bayous as soon as the pumps were put at work. At the time the samples were taken at the railroad bridge no current in either direction was perceptible. The stream, 75 to 100 yards wide and 40 feet deep, hardly deserved the name of river, it was in fact a great reservoir. Early in May the current turned backward from the Gulf in response to the pull of the irrigation pumps, and salt water in a few weeks filled the bayous. Not only was the Mermentau River itself salt but its tributary bayous, the Que de Tortue, Nez Pique, des Cannes, and Plaquemine were salt from source to mouth, a condition which continued without interruption until the close of the irrigation season. The rains which fell during July and August were too light to relieve the situation even temporarily, except in a few favored spots. The pumps, however, were kept at work, and salt water was delivered on demand of the farmers under the canals and by a majority of them poured over the growing fields.

EFFECTS OF SALT WATER ON THE CROP.

It is interesting to note the apparently varying results reached by the rice farmers who irrigated with salt water. In some localities a considerable area of blackened and dead rice would be relieved by cuts or fields of green and apparently healthy plants which seemed to promise a full crop. Many explanations of this peculiar condition were offered. It was thought that where the land was dry and greedily absorbed the salt water the rice plants were killed in a few days, or hours in some cases, but that where the soil was already saturated with fresh water which stood in measurable quantity upon the surface, the dilution of the salt flood was sufficient to enable the plants to live. Another view prevails to a limited extent, that in the fields which are saturated with fresh water the salt water may be used with some degree of safety by

pouring it on the land in large quantities and then draining it off before evaporation increases the percentage of salt in solution or brings about crystallization. which is destructive in all cases. In the heavy clay soils where natural absorption is very slow, rapid flooding and withdrawal of salt water would reduce the evaporation of fresh water from the surface and at the same time maintain the necessary saturated condition. This may account for the crops harvested from March planting which averaged eight or more sacks of rice per acre in spite of the salt water used. In all cases of this kind, coming under the writer's notice, the plants were well along toward maturity before the salt water was used. The quality of the grain was, however, much inferior to the normal crop. Not only was the half-filled head the rule but the grain was soft and chalky instead of flinty and crystalline, yielding only a small percentage of first-class rice. The weight averaged about 140 pounds to the sack instead of 185 pounds, the usual weight; and the price obtained, as a rule, while somewhat increased because of the reduced crop, was appreciably below what normal grain would have brought.

The production of rice from the fields irrigated by salt water varied between 25 and 50 per cent of the average crop. Eight sacks per acre was a rarity and 6 sacks very uncommon, the rule being 2½ to 4 sacks. The average would certainly fall below the latter figure. Thousands of acres were not cut because it was evident that the yield would not justify the expense of harvesting and thrashing, and an acreage equally as great stood in the fields half grown, brown, and dead, until turned under by the plow.

EFFECT OF SALT ON THE LAND.

The fields on which large quantities of salt water were used in 1901 showed that the effect of the salt was not limited to the single crop. The rice on many such fields in 1902 was not good enough to warrant the expense of harvesting. On the contrary, dead rice stalks from 6 to 15 inches high were the rule in such fields. Abundant rains during the fall and winter of 1901–2, and the irrigation season following probably would have insured a normal crop, but these rains did not occur. Should the condition of inadequate rainfall continue another year and salt water in large volumes again be pumped upon these fields, the injury would probably be lasting. There may be some question as to the extent of injury to the soil, but not as to the existence of the injury. It is certain that the salt water used for irrigation the second year was more destructive than it was the first year, showing that the further use of the waters of the Gulf in irrigation should be avoided. It would appear wiser to trust to rains after the fresh water has been withdrawn from the bayous than to sea water which is more dangerous than drought. In the one case, loss of crop may occur; in the

other, not only loss of crop but also serious deterioration of soil is practically assured. It is possible, however, that there is a stage in the growth of rice when brackish water, not very salt and in limited quantity, may be used beneficially to the crop and with minimum danger to the soil. A simple and inexpensive test for per cent of salt which could be made by the farmer or his engineer at the pumping station would be of advantage under these conditions.

MEASUREMENT OF STREAMS.

It is manifest that the extension of the rice-growing industry in southwestern Louisiana and southeastern Texas will be measured, not by the acreage of land suitable for raising rice, but by the supply of fresh water available for rice irrigation. Of land there is a superabundance, but the volume of the fresh water, comparatively speaking, is limited and the problem of determining just what the supply of each of the streams amounts to, is of great interest both to the owners of irrigation plants already established and to prospective investors in pumping machinery and rice lands.

The physical obstacles interfering with the measurement of bayous having a continuous flow toward the Gulf vary somewhat from those encountered in the more elevated districts where the current is marked and the stream shallow, but they may be overcome. The water in the bayou usually runs deep and the current is very slow, sometimes imperceptible. These conditions require sensitive and carefully rated current meters, which may be submerged to depths varying between 10 and 50 feet. The great width of these streams, which often reaches a hundred yards or more, is another serious obstacle, because careful and satisfactory measurements can only be made at considerable expense or in the few localities where bridges or ferries are found. This condition of continuous flow toward the Gulf, which is as yet characteristic of the majority of the streams, is not due to exceptional natural conditions but to the simple fact that the irrigation pumps are not yet numerous enough or large enough to withdraw the water passing down in quantities sufficient to reduce the surface level of the stream below that of the Gulf. When withdrawal to this extent does occur the current sets back inland. This condition is not always to be deplored, for large bodies of fresh water are usually stored in lagoons and broad lakes in the so-called sea-marsh district through which the streams flow for many miles before reaching salt water, the streams in this locality being little less than narrow but deep reservoirs which contain great volumes of fresh water. The supply of fresh water from this source is subject to great variation, however, for experience shows that in some of the streams where overappropriation prevails this stored water in 1902 was chiefly, if not wholly, salt. The volume of water passing any point is, therefore, not a measure of the supply. A survey

of such a stream with all of its tributaries and reservoir lakes might be made to determine its storage capacity, but the cost of such a survey would be considerable and to be of value would need to be carefully made. All lakes and at least one bank of the stream should be meandered and cross sections made at regular and reasonably close intervals. A survey of this character would provide data for determining the storage capacity of any bayou which, with the knowledge of the mean flow during the irrigating season, would furnish a basis for estimating the acreage that might be planted with reasonable assurance of maturing the crop, provided the water thus stored was known to be fresh enough to use. Analyses of the waters of these salt-infected streams, made during seasons of exceptional drought, seems to warrant the conclusion that in all deep-running streams the fresh water may be found flowing on the surface, while the denser salt water occupies the bottom and for a height above the bottom varying between one-fourth to one-half of the depth of the stream. The unknown value of this factor in the problem of determining the volume of the beneficial flood waters of such streams renders a correct solution still more difficult.

These difficulties are enumerated in the way of explanation of the problems to be overcome and not for the purpose of discouraging effort at measurements of streams which discharge fresh water into the Gulf a part of the year and supply salt water for the irrigation pumps the rest of the year. It is apparent that measurement of the discharge of all rivers and bayous in the rice district, whose currents do not yet suffer reversion due to overappropriation, should not be delayed until the actual presence of salt water seriously increases the difficulties to be overcome.

DUTY OF WATER AT LAKE CHARLES.

Two stations for the measurement of water used, rainfall, and evaporation were maintained in the rice district of southwestern Louisiana and southeastern Texas during the irrigation season of 1902. One of these stations was located under the canal of the North American Land and Timber Company, Limited, about 9 miles southeast of Lake Charles, La., and the other was an extension of the work begun last year under the canal of the Raywood Rice Canal and Milling Company, at Raywood, Tex. The soil in Calcasieu Parish, La., about Lake Charles, is more sandy than the soil around Crowley, where a station was maintained last year, and the surface of the ground is not so smooth, but is marked by low hummocks or knolls which the water can not cover because of their height. The tract of land selected near Lake Charles contained about 30 acres, but only the water used on 25 acres was measured. This tract was being used by Prof. S. A. Knapp, who is experimenting with many varieties of foreign rice imported by

him for the U. S. Department of Agriculture last year. The measuring flume was located in a small lateral which received its supply from the main canal of the company. It is about 100 yards from the head gate of the lateral and about 50 yards from the point where distribution began. The rain gage and evaporation tank were located close by. Irrigation was begun June 14 and concluded August 30, a period of 77 days. During this period the field received enough water to cover it to a depth of 23.64 inches. The rainfall during the irrigation season was 7.10 inches and the evaporation 11.53 inches. This left 19.21 inches of water to supply that absorbed by the soil and taken up by the rice plants during the period of growth. This is more water than was used at Crowley, La., in 1901,[a] a net depth of 12.04 inches. Difference in practice is chiefly responsible for this variation, but doubtless the sandy character of the soil at Lake Charles permitted greater absorption.

The following table shows the depth of water received by the Lake Charles rice field during the irrigation season, and also, the weekly rainfall and evaporation at this station:

Depth of water used on Lake Charles rice farm and the rainfall and evaporation each week of the irrigation season of 1902.

Week ending—	Flood water.	Rainfall.	Evaporation.	Week ending—	Flood water.	Rainfall.	Evaporation.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
June 21	5.78	0.30	1.03	August 9	0.51	1.00	1.30
June 28	5.14	.00	1.10	August 16	.54	.60	.70
July 5	4.48	.00	2.30	August 23	.45	.50	.60
July 12	3.09	.50	1.00	August 30	.43	.10	.60
July 19	1 78	2.50	1.10				
July 26	.88	1.30	.80	Total	23.64	7.10	11.53
August 2	.56	.30	1.00				

Duty of water under canal of the North American Land and Timber Company at Lake Charles.

Area irrigated	acres	25.00
Depth of water received from irrigation	inches	23.64
Depth of rainfall	do	7.10
Total depth of water received by land	do	30.74
Evaporation	do	11.53
Net depth of water received by land	do	19.21

The accompanying diagram (fig. 6) shows the days when water was applied and the depth to which the water used each day would cover the field. A comparison of this diagram with the diagrams showing dates of irrigation at Crowley and Raywood in 1901[b] shows a con-

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 113.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 113, pp. 23, 27.

siderable measure of agreement. In all these cases the heaviest irrigation was done comparatively early in the season; in fact, the greater part of the water was used between June 15 and July 15. It is noticeable, however, that irrigation at Crowley began on June 28, in 1901, and on June 14, just two weeks earlier, at Lake Charles, in 1902. Fifty-two per cent of the water was used upon Lake Charles field during the 17 days of irrigation in June, 39 per cent in July, and 9 per cent in August.

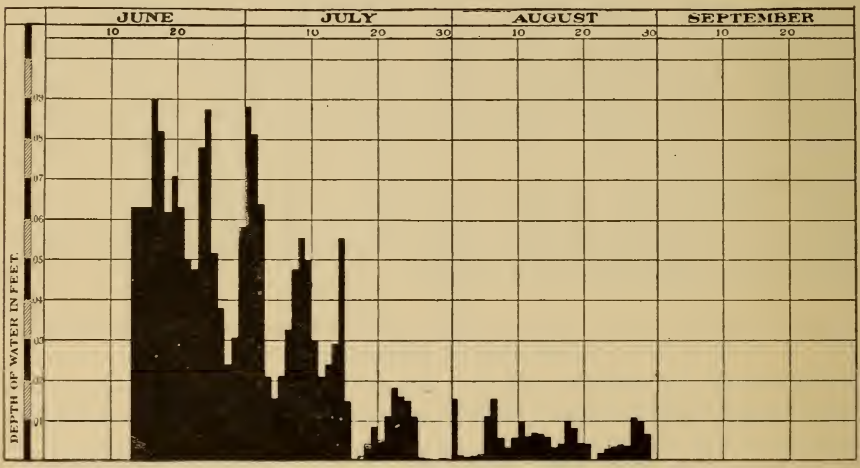

FIG. 6.—Diagram showing depth of water used on rice field at Lake Charles, La., and dates when irrigation occurred.

DUTY OF WATER AT RAYWOOD.

A tract of 545 acres under the canal of the Raywood Rice Canal and Milling Company at Raywood, Tex., was selected for the measurement of water used in irrigation of rice in 1902. This tract was supplied by a large lateral which took water from the main canal about 1 mile below the station maintained in 1901. The measuring flume with water register was placed in this lateral about 50 yards from the main canal, and the rain gage and evaporation tank were placed alongside. Aside from the greatly increased acreage, the conditions affecting the measurements carried on differed in no way from those encountered last year. Irrigation was begun June 14, the same date as at Lake Charles, but owing to the much greater area watered was not completed until September 13, a period of 91 days. During this period the field received from the canal enough water to cover it to a depth of 19.71 inches. The rainfall during the irrigation period was 11.08 inches and the evaporation 17.45 inches. From these records the net depth of water left to be drawn upon by the growing plants and taken up by the soil was 13.34 inches. This is a little more water than was used in 1901, the net depth for that season being 12.78 inches.

The table which follows shows the depth of water received by the Raywood field during the irrigation period covering 13 weeks, and also the rainfall and evaporation.

Depth of water used on Raywood rice farm and the rainfall and evaporation each week of the irrigation season of 1902.

Week ending—	Flood water.	Rainfall.	Evaporation.	Week ending—	Flood water.	Rainfall.	Evaporation.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
June 21	0.16	0.92	1.12	August 16	0.54	0.00	0.60
June 28	.19	4.40	1.35	August 23	2.59	.00	1.20
July 5	.11	.06	1.45	August 30	4.83	.00	1.28
July 12	.64	1.03	1.19	September 6	.90	.60	1.20
July 19	.00	1.20	2.54	September 13	2.55	.00	1.40
July 26	.00	2.57	1.00				
August 2	3.60	.30	1.00	Total	19.71	11.08	17.45
August 9	3.60	.00	2.12				

Duty of water under canal of the Raywood Rice Canal and Milling Company, at Raywood, Tex.

Area irrigated	acres	545.00
Depth of water received from irrigation	inches	19.71
Depth of rainfall	do	11.08
Total depth of water received by land	do	30.79
Evaporation	do	17.45
Net depth of water received by land	do	13.34

The diagram which follows (fig. 7) shows the days when water was applied and the depth to which the water supplied each day would

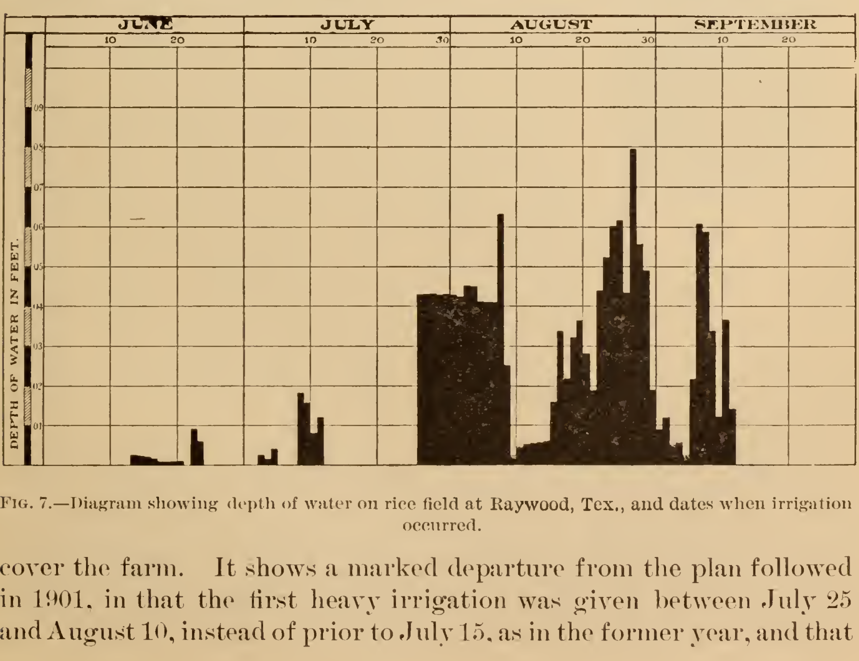

FIG. 7.—Diagram showing depth of water on rice field at Raywood, Tex., and dates when irrigation occurred.

cover the farm. It shows a marked departure from the plan followed in 1901, in that the first heavy irrigation was given between July 25 and August 10, instead of prior to July 15, as in the former year, and that

the great bulk of the irrigating was done during the month of August. This is partly explained by the delay experienced in getting necessary new pumps installed, but the table of rainfall, above, shows that between June 21, when irrigation began, and July 26, over 10 inches of rain fell. This heavy precipitation was evidently sufficient to supply the greatest necessities of the growing plants. Of the entire volume of water applied to the rice farm at Raywood, 2 per cent was used in June, 17 per cent in July, 65 per cent in August, and 16 per cent in September.

IRRIGATION FROM DEEP WELLS.

Irrigation from deep wells in the coastal plain region of Louisiana and Texas appears to have passed the experimental stage. The effort to secure a subterranean supply of water was greatly stimulated by the two seasons of deficient rainfall which closed with the harvest of 1902, but it did not originate because of drought conditions. Settlers upon prairie lands too far removed from the bayous to secure water therefrom for rice irrigation, because of the prohibitive cost of irrigation works, were the pioneers in the well-boring experiments which now promise, under careful management, a reasonable and permanent supply. The entire region, as far as bored, is underlain with saturated gravel and sand beds which are not exactly uniform in composition, but which, in general, may be said to offer the same problems to be solved. The artesian wells for rice irrigation extend from the eastern border of the rice district practically to its western limit on the Lower Rio Grande, in southern Texas. Comparatively few of these wells flow freely, but in all of them the water in the pipes stands at least as high as sea level, and in most of them much higher. There is quite a variation in the water level of wells in the same immediate territory, but the general statement may be made that in the case of new or unused wells in Louisiana the water in the pipes stands from 6 to 12 feet from the surface. There are, however, some flowing wells and many others in which the water rises to within 4 feet of the surface, and comparatively few cases where the natural level is lower than 12 feet. The wells in Colorado County, Tex., show the natural water level in that district to be 20 or more feet from the surface. These wells are not artesian in any sense, few, if any, being 50 feet deep. They are, however, an important source of water supply for rice irrigation in that part of the State.

Well boring in the rice district is not retarded or made costly by serious or insurmountable natural obstacles in the soils pierced. The material passed through above the gravel beds consists of alternating strata of sands and clays, the latter predominating. Quicksands are not very common, and when found are seldom thick enough to force abandonment of the well. In Louisiana the wells visited varied

between 160 and 300 feet deep, and the water-bearing gravel stratum was between 36 and 100 feet thick.

The earlier wells were more shallow than those bored later, and much trouble was experienced by placing screen pipe in the beds of fine sand which were pierced. As long as a considerable body of water was obtained from these strata the pumps also brought up great volumes of the sand, and the suction finally broke the screens and in many cases the entire pipe had to be removed. This was found to be a useless expense and a source of considerable annoyance. It is the universal practice now to pass through all sand strata to the coarser gravel beds, and the depth to which these beds are entered is much greater than during the first experiments. In order to get the greatest possible supply of water from the wells the length of screened pipes used has been increased from 20 to more than 100 feet in some instances, the aim of the irrigator being to supply screened pipe for as much of the saturated gravel deposit as his well penetrates (fig. 8).

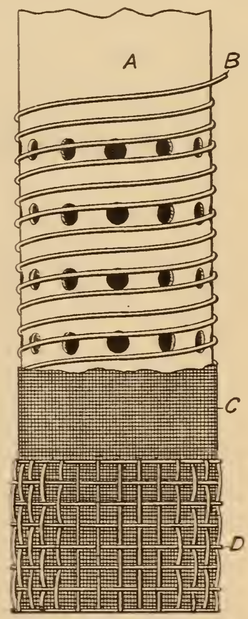

FIG. 8.—Strainer used in deep wells: A, iron pipe; B, wire wound on pipe; C, brass woven-wire cloth; D, heavy woven-steel cloth.

The depths of the artesian wells vary not only in the different districts, but in the same district, and wherever failure to secure a sufficient supply has been experienced it generally may be charged to failure to go deep enough. Where wells are bored in the same immediate neighborhood, those which go the deepest into the water-bearing gravel are the most efficient. Near Crowley, La., a number of wells were bored in 1902 upon small rice farms whose owners feared the prevailing drought conditions would prevent the large canals from furnishing the necessary volume of water at the time needed or that the water would be salty. Many of these wells were not bored until the month of June, and some did not furnish water before July 15. The deepest well of those examined went down 285 feet, but the majority were from 25 to 50 feet shallower. The first wells around Jennings, La., were between 150 and 170 feet deep, but the practice now is to put them down much deeper, and the same may be said of those near Welsh, which average 200 feet or more, the screened pipe being 40 to 65 feet in length. There is also a tendency to bore larger wells. At the beginning 6 and 8 inch wells were made, but this practice is being discontinued, especially in cases where the farmer hopes to extend the acreage of rice planted without serious additional expense on account of wells. The experience of some farmers shows that one deep 10 or

12 inch well will produce more water than three 8-inch wells of shallower depth. This is due in some measure to the reduced friction and less liability to choking up of the screen, a condition not so likely to prevail in the case of a larger well. Then again, where several small wells are connected to one pump there is much more liability to leakage of air at the numerous pipe couplings. Experience shows that more satisfactory results are reached by sinking larger wells and fewer of them.

INSTALLING PUMPS.

The centrifugal pump is as popular with irrigators from artesian wells as with those who use surface waters, the vertical submerged pump being the most used. The pump is set in a pit whose depth depends upon the level of the water in the well. The pit should be deep enough so that the pump will remain submerged when the water level is lowered by pumping. If the level of the water in the pipes gets much below the impeller or piston, the pumps have to be primed or lowered.

As the water falls, greater power is required to operate the pumps on account of the increased lift. Many small pumping plants in 1902 failed to meet the expectations of the planters because of insufficiency of power. The traction engine ordinarily used in farm work was pretty generally employed to operate the smaller deep-well pumps, but with larger wells, horizontal stationary engines and boilers of greater power are desirable in order to meet all contingencies likely to arise, including the considerable fall of water level, which necessitates a material increase of speed in the pump to maintain the necessary discharge.

THE FALL OF WATER IN WELLS.

The fall of water in the irrigation wells was common to all parts of the rice district, but the extent of the fall varied considerably. Near Crowley the total lifts of the pumps in some instances were doubled, the fall of the water level being 12 to 15 feet. The ultimate effect of this lowering of the water level can not be stated at this time. Six weeks after the pumps stopped the water in the wells generally had risen but little, but there is small reason to doubt that it will return to its original level in time, probably long before the beginning of the next pumping season. The entire rice district has suffered from two years of short rainfall, and the effect of this shortage may be to lower the level of the gravel-bed supply until such time as greater precipitation with reduced drain from the pumps allows the water to return to normal level. It appears, however, that the well supply is not unlimited, but that the number of farms which may continually be watered from shallow artesian wells must be determined by the experience had

in each district. At Welsh, La., about 30 miles west of Crowley, the water level in the artesian wells was reduced about 10 feet during the irrigating season, but the return to its former level was much more rapid than in the wells north of Crowley. This comparatively rapid rise seemed to assure the farmers of that neighborhood of a supply next year equal to that available the present year.

COOPERATION SUGGESTED.

Should experience show that the volume of subterranean water is limited, there is little doubt that a resort to cooperation in the planting and irrigating season would increase the duty of the available supply. Reduction in the water levels of the wells is more rapid near the close of the season when all the pumps are being run to their full capacity night and day. A division of the fields into two classes, one of early and the other of late planting, would extend the period of pumping and greatly reduce the volume withdrawn at any one time and during the period of growth when the greatest amount is needed. This suggestion is based upon the theory that the fall of the water level in any well affects in some measure the level of the water in the wells of adjacent farms. Owing to the fact that idle wells in the rice district are very scarce, if any exist, and that no observation has been made of them to determine this question, the inquiry can not be satisfied at this time.

COST OF BORING WELLS.

The cost of boring artesian wells is fairly uniform where there are no especially difficult strata to be pierced. Few wells are abandoned because of deposits of quicksands. In 1898, when well boring for irrigation began, the cost ranged between $2.50 and $4.50 per linear foot. This price included the wrought-iron casing, the contractor turning the well over complete and ready for connection with the pump. The average cost of wells at the present time, 1902, is not far from $3 per foot for 8-inch wells, the price going higher for 10 and 12 inch wells. The practice of contracting for wells and pumps connected and in condition for immediate use appears to be growing.

COST OF PUMPS.

The average cost of irrigation pumps, as shown by the catalogue prices of a number of manufacturers, is $210 for 6-inch, $330 for 8-inch, $460 for 10-inch, and $650 for 12-inch pumps; but these centrifugal pumps were delivered to the purchaser at his nearest railroad station at prices sufficiently reduced in most cases to bring the cost of the pump, installed and ready for work, within the average catalogue price. Sometimes the total cost was materially less than the catalogue price of the pump.

COST OF OPERATING PUMPS.

In the cost of operating irrigation pumps is included cost of fuel, wages of engineers, and repairs. The mineral oil obtained from the wells at Beaumont, Tex., Jennings, La., and other localities in or near the rice districts has practically superseded both wood and coal as a fuel. The cost of necessary fittings (fig. 9) to permit the use of oil is comparatively small, the same consisting essentially of two small iron pipes, one connecting with an oil tank or reservoir and the other with the main boiler which furnishes the steam. Through a small nozzle, the volume of whose discharge within the steam pipe is controlled by a valve, the oil is discharged and at once vaporized, leaving the steam pipe in a gaseous form, which gives a high and uniform temperature. In the large pumping plants the oil is forced to discharge regularly by the use of a small steam pump, which materially adds to the cost of this apparatus. The cost of fuel oil in 1901 ranged between 20 and 65 cents per barrel, delivered at nearest railroad station f. o. b. In

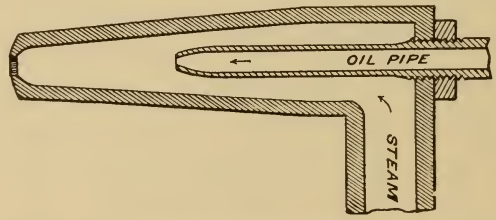

FIG. 9.—Section of oil burner, showing method of vaporizing oil by steam.

1902 the price was somewhat higher, especially toward the close of the irrigation season and in cases where contracts for delivery during the entire season had not been entered into. The variation in price noted was chiefly due to freight charges, which of course increase with the length of haul. The average cost of operating a 6-inch pump is about $10.50 per day and of an 8 or 10 inch pump about $12.50 per day of twenty-four hours' run. This estimate is based upon the use of oil as fuel, and wages of engineers at $2 per day with board, and incidental repairs during the season. In some localities engineers are hired for $1.50 per day, but the service rendered has not been entirely satisfactory.

The following table was constructed from figures obtained from individual rice farmers who had irrigated rice successfully for one or more seasons from artesian wells upon their premises. The exact returns from any individual are not given, the table showing average results reached:

Cost of operating pumps and the areas irrigated.

Artesian wells.				Pumps.				Cost of operating plant 24 hours.			
								Fuel.			
Diameter of pipe.	Depth of well.	Length of screen.	Height of lift.	Kind used.	Diameter of discharge.	Engine used.	Boiler used.	Kind.	Cost.	Wages of engineers, etc.	Area irrigated.
In.	*Feet.*	*Feet.*	*Feet.*		*In.*						*Acres.*
8	165–225	60	20–30	Vertical centrifugal.	6	16-horse-power traction.	30 to 40 horse-power traction.	Oil .. Wood	$3.00–$5.00 6.00–10.00	$3.00–$5.00	125–160
10	200–285	60	20–30	.....do....	8	16-horse-power traction to 40-horse-power horizontal.	40-horse-power traction to 50-horse-power horizontal.	Oil ...	4.00– 6.00	3.00– 5.00	225–250
12	200–275	60–80	8–20	.....do....	10	18-horse-power traction to 40-horse-power horizontal.	40-horse-power to 50-horse-power.	Oil ...	4.75– 8.25	3.00– 5.00	210–550

FOUNDATIONS FOR WELL PUMPS.

In all cases coming under the notice of the writer the foundations for artesian-well pumps consisted of framework in the bottom of the pit. This is substantial enough for centrifugal pumps having rope or belt transmission, but is not permanent in character. The wooden framework will last some time, but will have to be replaced on account of decay often enough to make it expensive in the end. However, the farmers who are making their first experiments with wells will use the cheapest pump foundations until they are certain the well itself is going to be a success.

SUMMARY OF DEEP-WELL RECOMMENDATIONS.

The experience had during four years of irrigation from deep wells in Louisiana and Texas should be of value to those who expect to bore wells in the future, and the following general suggestions, based upon that experience, are offered:

(1) Put down a large bore well. It will furnish much more water, the screen will work more satisfactorily, there will be less friction in the pipe, and the cost of a 10 or 12 inch well over that of an 8-inch well is not large.

(2) Go deep into the coarse gravel beds. One 10-inch well 250 feet deep has been known to deliver more water than three 8-inch wells in a battery, bored 20 feet apart and 165 feet deep, and it did not cost so much.

(3) Put plenty of screen at the end of the pipe. Sixty-five to 90 feet of strong, well-made screen on a 10 or 12 inch pipe is not too much. There is little danger of getting more water in the pipe than will be needed.

(4) Get a larger pump than the general estimate assigned for the work and then install a boiler and engine sufficiently large to meet all possible contingencies in the way of increased lift, etc. Inadequate power has been a common source of loss.

(5) Dig the pit for the submerged pump deep enough to allow of a considerable fall in the water level before the pumping season closes. The variation in the water level in 1902, in the different districts, was between 4 and 15 feet.

IRRIGATION FROM SHALLOW WELLS.

In Colorado County, Tex., water in sufficient quantities for the irrigation of rice has been found at a depth not greater than 45 feet. At a depth of 25 to 30 feet there is a bed of gravel which averages about 15 feet in thickness. The top of this stratum is composed of sands and fine gravel which becomes coarser with depth. The screens are placed close to the bottom of this stratum. The saturation of the gravel bed appears to be about uniform, but the drain of the pumps reduces the level of the water during the irrigation season. These wells cost, complete, about $225.

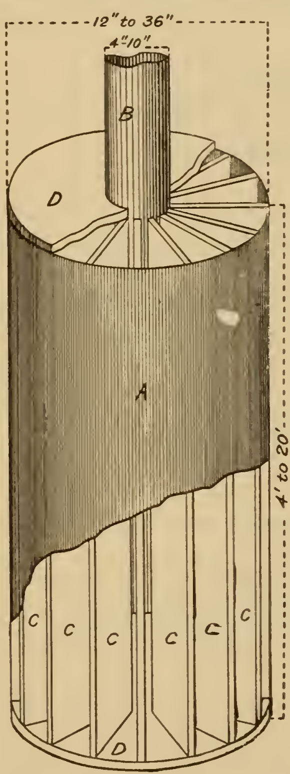

FIG. 10.—Strainer used on shallow wells in Colorado County, Tex.: A, woven-wire cloth, 10 to 40 meshes to the inch; B, iron pipe; C, supports radiating from pipe to prevent collapse of screen; D, ends of strainer.

The wells characteristic of this district are dug by hand. They are from 8 to 12 feet in diameter, and go down to the water-bearing gravel and sand stratum. This large well is used as a pit in which a centrifugal pump is set on framed foundation. From the bottom of this pit one or more iron pipes from 4 inches to 10 inches in diameter are sunk into the gravel. These pipes, in the region about Eagle Lake, are supplied with strainers 12 to 36 inches in diameter and 4 to 20 feet long. The character of this strainer is shown in fig. 10. The iron pipe itself is not perforated or wrapped, as in the case of the deep wells, but goes down to within a foot of the bottom of the strainer. The ends of the strainer are of wood and are nailed to the supports of the screen and

serve to maintain the screen in position as well as prevent the entrance from top or bottom of sand or gravel into the pipe.

PUMPS USED.

The 5-inch pumps customarily used in these shallow wells are of the vertical and horizontal centrifugal patterns and they are put in position in a manner similar to that described for deep wells. In the case of the horizontal pumps both belt and rope transmission are used, while belts only were found transmitting power to the vertical pumps. Power is supplied by a great variety of engines, the horizontal steam and gasoline engines being most common. The gasoline engine is popular and has been found economical and especially satisfactory in cases where the water in the shallow wells is not the best for steam making.

COST OF OPERATING PUMPS.

The cost of operating shallow-well pumps is the same as for similar sizes of deep-well pumps, except that heavier engines and more power are often needed on account of higher lifts. Twenty-two to 26 horsepower horizontal gasoline engines are successfully used to run the 5 or 6 inch pumps commonly used in the district. These engines require 50 to 60 gallons of gasoline in twenty-four hours, the gasoline costing 10 cents per gallon. While new, they do not require a skillful engineer to operate them, but a common laborer at $1 per day was employed during the entire season of ninety days. In such cases the cost of operating is about $6.50 per day, and from 65 to 100 acres of rice were raised. The average cost of a shallow-well plant complete and ready for work is about $1,600 when the centrifugal pump has a discharge pipe not greater than 5 inches in diameter.

VALUE OF CROPS RAISED.

The value of the crop of rice raised by irrigation from artesian wells varies with local conditions of soil and water supply, the deep wells of same diameter irrigating more land than the shallow wells. The yield of the farms visited throughout the rice district varied between 8½ and 15 sacks of rice per acre irrigated. The variation in acreage irrigated from the deep wells is shown in the table on page 191. In the case of the shallow wells with minimum acreage and minimum yield the return for the first year about equaled the outlay for irrigation works, but in the case of a maximum yield of 15 sacks per acre on 100 acres the gross cash return was sufficient to meet the cost of irrigating machinery and well and leave a net balance for the farmer equally as great as this cost. Crops of this character are not the rule, however, but are cited to show what may be done under favorable conditions.

WATER RIGHTS.

The effect of two consecutive seasons of minimum rainfall upon the production of rice in Louisiana and Texas has been seriously felt in those districts where overappropriation from the rivers and bayous prevails. Many streams which discharged an abundance of water for the rice plantations along their banks a few years ago were found short in supply in 1902. This shortage was due partly to the prevailing condition of drought and partly to the increased number of pumps and canals which these streams are now called upon to supply. The planters who draw water from streams which furnish brine for irrigation the latter half of the season are being forced to face a disagreeable situation. Those who began to pump water for irrigation six or seven years ago have witnessed the destruction of valuable crops during two successive seasons without discovering any solution of the difficulties which confront them. It is no gratification to them that the newer arrivals also have met with failure, nor has the latter derived profit from the contemplation of a ruined crop which is the common lot. Regretting an investment that promises to become permanently unprofitable as more pumps are established upon the banks of the overappropriated streams will not solve the problems involved. Conditions seem to warrant the conclusion that some method of establishing permanent rights to water and of dividing the supply in accordance with those rights by a recognized and disinterested authority is a pressing necessity. In the absence of such rights and control the element of hazard is sure to become a much more important factor in the business of rice growing than now obtains, for no planter can say in advance of the planting whether his neighbor or himself will suffer the greater loss. The overappropriated stream, which is now the exception, will soon become the rule if not the prevailing condition.

Chief among the larger water courses in which overappropriation prevails, and which may be cited as an example to show the effect of this condition upon the rice crop, is the Mermentau River in Louisiana. A successful and profitable crop upon all the rice land now leveed and under canal along this river and its tributaries is an impossibility unless a condition permitting early planting and followed by excessive rainfall prevails. This is not likely to be the rule and two questions arise: How shall the water of this river be divided among present appropriators, and what shall be done to prevent additional appropriations from this already heavily overloaded stream? It is manifest that a few more seasons like 1901 and 1902 will so reduce the value of existing water privileges along this stream that many farmers will be forced out of business. The times of their failure will be determined by their endurance. This certain and drastic method of reducing the drain upon the river might be tempo-

rarily effective, but would not solve the problem, for the present incapacity of the stream would be forgotten as soon as a few seasons of profitable crops were experienced. The writer believes that no proper security for the business of rice growing along overappropriated streams in Louisiana will be possible until provision is made by law for the establishment of the right to appropriate water for irrigation and also for fixing the status of appropriators from the same source of supply by recognizing the doctrine that priority in time of appropriation gives the better right. Provision for securing official regulation and control of diversion is equally important.

In a measure the conditions which prevail in Louisiana also obtain in Texas. Owing to the rapid extension of the rice fields in southern Texas indications point to a possible failure in the water supply of some streams whose fall is too great to permit of the invasion of salt water after the fresh water is withdrawn. In the absence of opportune rains crop failure in these localities may not be as complete as in the districts where the evil effects of drought on the growing rice are augmented by floods of brine, but the necessity for adequate control of diversion will be as strongly felt as elsewhere. In Bulletin No. 113 of the Office of Experiment Stations the writer briefly discussed the irrigation laws of Texas and indicated certain changes which were believed desirable in order that agriculture by irrigation might receive that support and encouragement to which it is justly entitled because of its growing importance among the industries of the State. The experience of the rice growers during the irrigation season of 1902 emphasizes the opinions therein expressed.

THIRD PROGRESS REPORT ON DISCHARGE AND SILT MEASUREMENTS ON TEXAS STREAMS.

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SCOPE OF THE WORK.

During the year 1902 gage height and discharge measurements have been made on the Brazos River at Jones Bridge, Brazos County, and also at Richmond, Tex. Similar measurements have also been made on the Colorado River at Wharton, Tex. Both the Richmond and Wharton measurements were made for the purpose of determining the amount of water available for rice irrigation along the lower reaches of the Brazos and Colorado rivers for those months during which irrigation is most practiced in the Texas coastal plain. At the Jones Bridge frequent collections of samples of the river water for silt determinations have been made in the manner described in previous reports, but at much shorter intervals of time than has been the case heretofore. Some samples of Rio Grande water were received from the consulting engineer of the International (Water) Boundary Commission, and also a few samples were collected from the Colorado River at Wharton.

DISCHARGE AND SILT MEASUREMENTS.

BRAZOS RIVER AT JONES BRIDGE.

Daily gage heights have been taken throughout the year by means of a graduated chain in the manner described in previous reports. Samples of water for sediment determinations have been collected almost daily in tin collecting cans and the observer has kept daily notes on the appearance of the water. Failure on his part to fully appreciate the importance of daily collections at times when the river carried considerable sediment led to their omission on a few days, at times when it would have been very desirable to have had collections made. On the whole, however, the work of collecting samples has been much more thoroughly done during the year covered by this report than has been the case for preceding years, so that fewer interpolations have been necessary.

The extreme range of gage heights for the year has been 43.15 feet, the lowest stage occurring March 7 to 13 and the highest on August 1. The river overflowed its banks on July 28 and remained out until August 2. Throughout the State of Texas the rainfall was very much below the normal until late in July, and crops were backward in consequence. The overflow destroyed all farm crops where the water covered them, and the small area in cotton in the bottoms which escaped was attacked by the boll weevils, which in consequence of the destruction of so large a cotton acreage by the overflow concentrated upon the plants which remained alive and almost destroyed the remaining bottom crop.

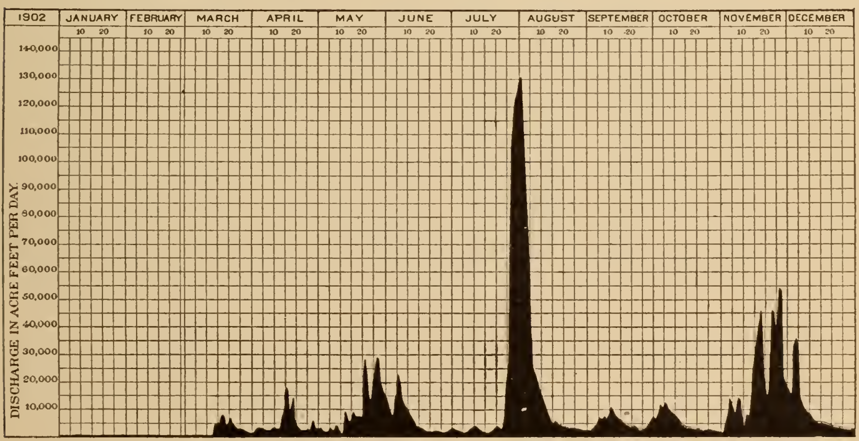


FIG. 11.—Diagram showing discharge of Brazos River at Jones Bridge, Brazos County, Texas.

The discharge diagram shown in fig. 11, taken in connection with the corresponding diagram for discharge at Richmond (fig. 13, p. 214), shows that up to the point at which overflow occurred the rise in the river was very rapid and continued slowly until the crest was reached. The rate of rise at Richmond was unusually slow, which was due to the comparatively slow return of the water to the channel at points higher up the river. The water did not get out of banks at Richmond. Both diagrams show a very rapid rate of fall when the water began to go down. Usually the conditions show just the reverse. The following table shows the daily discharge of the Brazos at Jones Bridge for 1902:

Discharge of the Brazos River at Jones Bridge, Brazos County, Tex., 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Acre-ft	*Acre-ft*	*Acre-ft*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
1	488	488	464	1,242	2,697	11,703	3,245	130,770	2,594	7,338	1,123	16,294
2	488	488	464	3,104	2,321	8,600	3,245	116,580	2,595	6,726	1,051	15,025
3	488	488	464	3,245	1,710	6,694	2,442	89,360	2,594	11,986	6,641	33,170
4	488	488	464	3,104	1,466	22,160	2,321	67,560	2,670	10,536	13,990	36,352
5	464	488	464	2,698	2,321	19,912	2,321	40,370	3,052	9,876	12,380	18,364
6	464	488	442	2,087	2,568	15,614	1,761	28,287	4,149	12,280	8,134	16,080
7	464	464	422	1,609	1,418	13,737	1,466	21,550	6,898	11,400	6,641	13,078
8	464	464	423	1,761	3,693	10,616	2,828	16,940	6,212	8,584	14,403	10,822
9	464	464	422	1,813	3,693	9,455	4,506	14,095	6,127	8,044	13,178	9,688
10	464	442	423	3,465	1,418	6,799	3,693	11,693	7,338	6,468	3,990	8,403
11	464	442	422	2,569	1,079	5,496	2,896	10,064	5,621	5,620	8,222	7,777
12	464	442	423	3,173	9,330	4,506	2,202	8,766	9,134	4,877	7,336	7,336
13	464	442	422	4,336	7,450	3,927	1,761	7,688	10,822	4,552	8,858	6,813
14	464	442	536	7,672	5,310	3,318	1,561	5,537	9,312	3,990	13,685	5,706
15	464	442	4,506	16,932	6,284	2,828	1,513	4,877	7,600	3,207	24,043	5,454
16	464	442	2,828	17,783	9,330	2,505	1,609	5,874	6,468	2,822	20,738	5,290
17	442	442	7,120	8,840	7,672	2,029	1,920	5,537	5,874	2,670	39,205	5,123
18	442	442	8,362	13,737	7,120	1,813	3,465	4,958	5,790	2,293	45,630	4,958
19	442	488	5,883	7,672	7,120	1,658	4,336	4,796	5,290	1,995	30,890	4,796
20	442	488	4,853	5,125	6,284	1,813	2,569	4,552	4,877	1,849	19,370	4,552
21	442	488	4,592	3,616	33,075	1,867	2,966	4,231	4,633	1,995	14,195	4,310
22	442	464	6,180	2,763	25,970	1,561	3,465	4,149	3,753	1,482	32,495	4,149
23	442	464	3,392	2,144	14,660	1,418	3,848	4,070	3,911	1,337	45,165	4,070
24	442	464	2,965	2,087	11,564	1,329	22,846	3,991	3,207	1,995	44,860	3,832
25	464	464	2,697	2,261	31,910	1,200	24,170	3,675	2,975	1,922	38,050	3,753
26	488	442	2,321	2,144	27,025	1,119	54,070	3,439	2,900	1,922	63,980	3,586
27	488	442	1,867	1,920	33,788	1,466	103,330	3,362	2,975	1,922	36,070	3,586
28	488	442	1,658	5,688	19,548	2,321	119,120	3,130	3,362	1,849	21,430	3,586
29	488	....	1,466	3,245	16,600	2,828	123,820	2,975	5,454	1,555	19,598	3,518
30	488	....	1,285	3,104	15,134	3,771	126,650	2,747	8,495	1,410	18,252	3,439
31	488	....	1,466	....	15,134	....	129,570	2,747	....	1,265	....	3,362
Total	14,448	12,944	69,696	140,939	334,692	174,063	765,515	638,370	156,682	145,767	633,603	276,272

The measurements made during 1902, especially at high stages of the river, show very much smaller discharges than the measurements at the same stages showed in 1900. The maximum velocity at a stage of 41.6 feet, observed April 29, 1900, by floats, showed something over 11 feet per second at the surface, or something over 7½ miles per hour. The writer did not have an opportunity to make a measurement at a similar gage height during 1902, but others who had reported something less than 6 miles per hour at the same or a higher stage. Current-meter observations for the two years show that after the river had reached the half-bank-full stage, at any rate, velocities were considerably less during 1902 than they were during 1900. This is partially due to the fact that the frequent overflows have caused the banks to cave, carrying with them many large trees, which in many cases remain in the channel, where they impede the current considerably. This would not account for the very great difference in discharges, however, and some other explanation must be found. It may be accounted for in part by the fact that for the high-stage measurement made on April 29, 1900, the velocity was determined from float measurements, though erroneously appearing in the printed report as having been made with the current meter. Moreover, that measurement was made on a rising stage of the river, while all the measurements obtained at high stages during 1902 were made with the river rapidly falling. The highest measured

discharge in 1902 was at a gage reading of 26.7, as against 41.6 in 1900. Measurements made at Richmond, however, at high stages and on a rising gage, still show much less water coming down than was found for the Jones Bridge station during 1900.

Attention is called to the very much greater total discharge for the months of June, July, August, and September at the Richmond station—2,433,260 acre-feet passing that point, as against 1,734,630 acre-feet passing Jones Bridge during the same time (see p. 198). It must be borne in mind, however, that no attempt has been made to estimate or measure the volume of water which passed the latter point outside of the regular channel of the river, and undoubtedly a large amount did pass across the overflowed bottoms. Moreover, the Navasota River and the Yegua, as well as many creeks, empty into the Brazos River between the two stations. Navasota River was very high for a considerable period of time, and both it and the Yegua carry large quantities of water at high stages.

The following tabular statement shows the run off, by months, of the drainage area of the Brazos above the Jones Bridge station. The run off has been computed, both inclusive and exclusive of that portion of the watershed lying above the 3,000-foot contour, for reasons given in the report of 1900:

Run off from drainage area of the Brazos River above Jones Bridge during 1902.

Month.	Mean discharge.	Discharge for month.	Run off.			
			For 37,400 square miles.		For 30,150 square miles.	
			Depth.	Per square mile.	Depth.	Per square mile.
	Cu. ft. per second.	*Acre-feet.*	*Inches.*	*Cu. ft. per second.*	*Inches.*	*Cu. ft. per second.*
January	235.0	14,448	0.0072	0.0063	0.0090	0.0078
February	233.1	12,944	.0065	.0062	.0081	.0077
March	1,133.5	69,696	.0349	.0303	.0433	.0376
April	2,368.5	140,939	.0707	.0633	.0877	.0786
May	5,443.3	334,692	.1678	.1455	.2082	.1805
June	2,925.3	174,063	.0872	.0782	.1083	.0970
July	12,449.8	765,515	.3838	.3329	.4761	.4130
August	10,382.4	638,370	.3200	.2776	.3970	.3444
September	2,633.3	156,682	.0786	.0704	.0974	.0873
October	2,370.8	145,767	.0731	.0634	.0907	.0786
November	10,648.6	633,603	.3177	.2847	.3941	.3532
December	4,493.3	276,272	.1385	.1201	.1718	.1490
Total for year	....	3,362,991	1.6860	....	2.0917	....

Below is given the general results of all the discharge and run off measurements that have so far been made on the Brazos River:

Total discharge and run off, by years, from August 1, 1899, to December 31, 1902.

Period.	Discharge.	Run off.			
		For 37,400 square miles.		For 30,150 square miles.	
		Depth.	Per square mile.	Depth.	Per square mile.
	Acre-feet.	*Inches.*	*Cu. ft. per second.*	*Inches.*	*Cu. ft. per second.*
August 1 to December 31, 1899	1,165,310	0.5840	0.1027	0.7250	0.1274
January 1 to December 31, 1900	8,706,796	4.3523	.3216	5.4136	.3991
January 1 to December 31, 1901	976,602	.4897	.0361	.6075	.0448
January 1 to December 31, 1902	3,362,991	1.6860	1242	2.0917	.1541

In order to determine the percentage of total silt to total discharge with more precision than had been possible during the periods covered by previous reports, the writer instructed the observer at the river to take samples at short intervals, particularly when the appearance of the water indicated a change in the amount of sediment carried in suspension. Later on the observer was instructed to take daily samples of the water, and this he began to do about the middle of April, but occasionally failed to do so for several days at a time. Moreover, some of the samples collected were spoiled by reason of imperfectly cleaned bottles. A much closer estimate of the daily silt discharge has been secured, however, than has been possible heretofore.

Nearly all the samples were collected in tin collecting cans, as described in the 1900 report. In determining the percentage of silt in any sample the water was thoroughly shaken up and poured into a tube of known capacity and allowed to stand until all the sediment had gone to the bottom. The clear water was then decanted off and the sediment at the bottom washed into a graduate, which was then filled with water to a depth of about 7 inches. After standing for one week the volume of sediment was read in the graduate, and this divided by the capacity of the original settling tube yielded the ratio of sediment to the volume of water as collected. This has been reduced to percentages in the table which follows. Where more than one sample was collected at a time the mean of the resulting percentages was taken and entered in the table. Some of the samples settled practically clear in as short a time as two hours, but the great majority took from four to six hours to become clear. Those samples collected from November 11 to December 9 took from twenty to thirty hours to settle clear, and one sample, taken on April 30, required one hundred and fifty hours to become clear.

Silt determinations on water from the Brazos River at Jones Bridge during 1902—Percentages at the end of one week, by volumes.

Day.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1					0.652		0.767	0.963	0.029	0.625		0.758
2		0.000	0.000		.315	3.252	.613			1.539	0.070	
3					.250		.524	.889		2.130	.531	1.063
4					.159	2.250	.391	.726	.029	2.041	.535	.889
5	0.000				.309	1.592	.398			1.811	.432	.584
6					.204	1.605	.227	.994	.029	1.288		
7					.287	1.749	.227	.937	.398	1.613		.370
8		.000		0.228	.429	1.149	.227	.902	.525	1.329		
9			.000		.355	1.074	1.657	.895	Trace		2.163	.408
10				2.469	.490	1.290	1.000		.318	1.281		.379
11					.245	1.574	1.154	.671	.318	.902	1.543	.197
12	.000				2.031		1.125	.690	Trace	.556	1.516	.197
13				1.214	2.148	2.188	.424	.460		.350	1.351	.197
14				.927	1.895	5.385	.177	.207	.798	.300	.736	.135
15					1.724	2.099	.177	.207	.548	.189	2.065	
16		.000	.265	2.449	1.687	1.749	.177	.207		.189	1.189	.077
17				1.326	1.452		.204		.874	Trace		.117
18				2.187	1.188	.920	.204	.093	1.875	Trace	1.375	Trace
19	.000		1.441	2.012	1.543	.337					.928	
20				2.301	.816	.262	.420				.710	Trace
21				1.194		.262	.938		.928	Trace	.729	Trace
22				.763	2.443	.262	1.459				1.696	Trace
23		.000	.661	.524	1.749	1.167			.309	.053	1.074	
24				Trace			3.550	.029	.167		.742	
25				.313	1.917		8.018	.029	.167		.559	.043
26	.000			.153	2.175	.278	2.385	.029			1.563	
27			.245	.194	2.192	.583	1.820		.167		.690	.061
28				.398	1.633		1.156	.029	.336		.525	Trace
29			.258	2.315	2.730		.981		.336			
30				1.895	2.608	.145	1.142					.000
31					4.936		.875					

Two samples of Brazos River water were allowed to stand for a period of twenty-one weeks—practically five months—and the amount of sediment in each tube was read once a week. One of these was collected on June 14, and at the end of one week showed 5.385 per cent of sediment; at the end of one month it showed 5.09 per cent; at the end of two months, 4.97 per cent; at the end of three months, 4.82 per cent; at the end of four months, 4.565 per cent; and at the end of five months, 4.35 per cent, a total reduction in five months of about 19 per cent of the percentage at the end of one week. The other sample was taken on July 25, and at the end of one week showed 8.018 per cent of silt. At the end of one, two, three, four, and five months the percentages were, for these periods respectively, 7.43, 7.25, 7.15, 7.085, and 7.01, a reduction in five months of about one-eighth of the percentage shown at the end of one week as against nearly one-fifth reduction for the other sample. The means of the percentages of these two samples at the end of one week, one, two, three, four, and five months, respectively, were 6.702, 6.26, 6.12, 5.98, 5.825, and 5.68 per cent. The reduction in volume of the silt for the mean of these two specimens, reckoned in terms of the percentage at the end of one week, amounted to about 6.5 per cent at the end of one month, 9 per cent at the end of two months, 11 per cent at the end of three months, 13 per cent at the end of four months, and 15 per cent at the end of five months. This would appear to indicate a uniform rate of subsi-

dence after the end of the third month, but when the weekly readings were platted to scale, it was clearly evident that the rate of subsidence, for these two specimens at least did not follow any definite law, but appeared to go in something like waves. The graduates in which the sediment was measured read only to half cubic centimeters, and by estimation to the nearest tenth, so that close observations could not be made. These samples contained the largest percentages of silt of any collected from the Brazos River, and considering the wide difference in their rates of subsidence no definite conclusions can be drawn as to the rate of subsidence or shrinkage of sediment from samples carrying smaller quantities of silt which may have originated in other localities. It should have been observed that both these samples carried a very red sediment, originating, probably, in the Permian formations of northwest Texas. The assumption made in previous reports that the shrinkage at the end of one year is approximately one-fourth of the volume or percentage of sediment as determined at the end of one week's settlement appears to be about as near an approximation for general reduction as the writer is able to arrive at in the light of tests so far made.

Investigations regarding the relative percentages of silt carried at various depths in any vertical were not extensively made during 1902, because the conflicting results obtained from previous tests indicated that no well-defined relation exists. Only one set of four samples was taken during the year, and this was defective because of an improperly cleaned bottle causing the sample taken from the bottom to become spoiled. This set was taken on April 13 and at the end of one week the top sample showed 1.166 per cent; that taken at one-third depth, 1.035 per cent; that at two-thirds depth, 1.104 per cent, and that from the bottom (which was spoiled) 1.549 per cent of sediment. Seven sets of three each were taken, but two of these sets were defective. The means for the remaining five were as follows:

Percentages of silt at different depths.

	Per cent.
From top	1.481
From mid depth	1.405
From bottom	1.455
Mean	1.447

One set of two samples taken from the top and bottom showed a higher percentage of silt carried by the sample taken from the top. This was also the case with 3 sets of two samples each taken during the year 1901.

For the entire period from August 1, 1899, to December 31, 1901, there were in all 27 sets of four samples each collected, and for these the combined results are given below:

Percentages of silt at different depths, means of 27 sets.

	Per cent.
From top	1.1281
From one-third depth	1.1554
From two-thirds depth	1.1931
From bottom	1.1644
Mean	1.1603

During the same period (from August 1, 1899, to December 31, 1902) there were 12 complete sets of three samples each worked up, for which the general results are as follows:

Percentages of silt carried at different depths, means of 12 sets.

	Per cent.
From top	1.3412
From mid depth	1.3323
From bottom	1.3092
Mean	1.3276

These results do not warrant the drawing of any definite conclusions regarding the distribution of silt in any given vertical. The 27 sets of four each would indicate that the surface currents carry the smaller percentages of silt and those at two-thirds depth the larger, while the 12 sets of three each would indicate that the larger percentage of silt was carried at the surface and the smaller at the bottom. However, both would indicate that the average quantity of silt was carried at about mid depth. This might have been expected, since the velocity at mid depth is but slightly greater than the mean velocity in the section. Merriman's Hydraulics, page 264, gives the mid-depth velocity as about 2 per cent greater than the mean. On the other hand, it might be expected that the greatest amount of sediment should occur near the bottom, or if not there, then at the point where the maximum velocity occurs; yet it appears to do neither. The majority of the samples collected from the bottom were taken with the tin collecting cans and not with the special water sampler provided by this Department. Hence very little, if any, rolling sand (of which there appears to be very little in this stream) was caught in these samples.

From the table of daily discharges and the table showing the percentages of silt at the end of one week's settlement the daily discharge of silt was computed and entered in the table below. On days for which no samples were taken or for which the samples were spoiled or lost, interpolation had to be resorted to in approximating the percentage of silt for such days. The gage height and the stage of the rise, together with the observer's daily notes on the appearance of the water, were considered in connection with the measured percentages preceding and following the day or days for which samples were missing, and it is thought that the results closely approximate the actual conditions. Where quantities so approximated appear in the

following table they are inclosed in parentheses, unless it appeared obvious that the percentage was the same as for days both preceding and following the days in question. Where the water showed only a trace of sediment, no attempt was made to estimate the quantity of silt discharged in twenty-four hours, and such days have been left blank in the table.

Daily discharge of silt, in acre-feet, for the Brazos River at Jones Bridge, Brazos County, Tex., 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	Perfectly clear all month.	Perfectly clear all month.	....	(3.1)	17.6	(468.1)	24.9	1,259.3	0.8	45.9	(0.7)	123.5
2			....	(7.8)	7.3	279.7	19.9	(1,072.7)	(0.7)	103.5	0.7	(120.2)
3			....	(8.1)	4.3	(184.1)	12.8	794.4	(0.8)	255.3	35.3	352.6
4			....	(7.8)	2.3	498.6	9.1	490.4	0.8	215.0	74.8	323.2
5			....	(6.7)	7.2	317.0	9.2	(343.1)	(0.9)	178.8	53.5	107.2
6			....	(5.0)	5.2	250.6	4.0	281.2	1.2	158.2	(32.6)	(75.6)
7			....	(3.7)	4.1	240.3	3.3	201.9	27.5	183.9	(19.9)	48.4
8			....	4.0	15.8	122.0	6.4	152.8	32.6	114.1	(302.5)	(42.2)
9			....	(4.2)	13.1	101.5	74.7	126.1	....	(104.6)	285.0	39.5
10			....	85.5	6.9	87.7	36.9	(87.7)	23.3	82.8	(59.8)	31.8
11			....	(51.4)	2.6	86.5	33.4	67.5	17.9	50.7	126.9	15.3
12			....	(50.8)	189.5	(81.1)	24.8	60.5	....	27.1	111.2	14.5
13			....	52.6	160.0	85.9	7.5	35.4	(86.6)	15.9	119.7	13.4
14			....	71.1	100.6	178.7	2.8	11.5	74.3	12.0	100.7	7.7
15			(11.9)	(372.5)	108.3	59.4	2.7	10.1	41.6	6.1	496.5	(5.5)
16			7.2	435.5	157.4	43.8	2.8	12.2	(58.2)	5.3	246.5	4.1
17			(92.3)	117.2	111.4	(26.4)	3.9	(8.3)	51.3	....	(509.6)	6.0
18			(121.3)	300.4	84.6	16.7	7.1	4.6	108.6	....	627.4	....
19			84.8	154.4	119.9	5.6	(17.4)	(3.8)	(79.3)	....	286.7	....
20			(58.3)	117.9	51.3	4.8	10.8	(3.2)	(58.5)	....	137.5	....
21			(45.9)	43.2	(826.8)	4.9	27.8	(2.5)	43.0	....	103.5	....
22			(49.4)	21.1	634.4	4.1	50.6	(2.1)	(22.5)	....	551.1	....
23			22.4	11.2	256.4	16.5	(57.7)	(1.6)	12.1	0.7	485.0	....
24			(17.8)	....	(213.9)	(10.6)	811.0	1.2	5.4	(1.0)	332.8	....
25			(13.5)	7.1	611.7	(6.0)	1,938.0	1.1	5.0	(1.0)	212.7	1.6
26			(8.1)	3.3	587.8	3.1	1,289.5	1.0	(4.8)	(1.0)	1,000.0	(1.8)
27			4.6	3.7	740.6	8.5	1,881.0	(1.0)	5.0	(1.0)	248.8	2.2
28			(4.1)	22.6	319.2	(10.4)	1,377.0	0.9	11.3	(0.9)	112.5	....
29			3.8	75.1	453.2	(8.5)	1,214.7	(0.9)	18.3	(0.8)	(117.6)	....
30			(3.2)	58.8	394.7	5.5	1,446.3	(0.8)	(55.2)	(0.7)	(127.8)	....
31			(3.7)	....	747.0	....	1,133.7	(0.8)	....	(0.6)	....	....
Total	0.0	0.0	552.3	2,105.8	6.955.1	3,216.6	11,541.7	5,040.6	847.5	1,566.9	6,919.3	1,336.3
Mean percentage	....	.0	.798	1.494	2.078	1.848	1.508	0.790	0.541	1.075	1.082	0.484

The table shows that the largest percentage of silt for one month occurred in May; the next largest in June. July showed the largest total discharge of silt for one month, and the percentage was also high. April, while showing but a small total quantity of silt, had a high percentage—nearly equal to July. January, February, and the first fourteen days of March were entirely without silt discharge, as the water was perfectly clear during this period. The total silt discharged for the whole year amounted to 40,082.1 acre-feet, and this divided by the total discharge of the river for the same time—3,362,991 acre-feet—gives an average for the year of 1.192 per cent at the end of one week's settlement and a probable percentage of 0.896 at the end of one year's settlement. The foregoing values of the average percentages for an entire year should be regarded as more reliable than those given in preceding reports because samples were collected so much oftener. The values previously given, except for the five months

from August 1 to December 31, 1899, are considerably higher than those found in 1902. However, the character of the watershed from which the bulk of the waters passing down the river originated has a marked influence upon the average percentage of silt carried in suspension. Water coming from the red lands on the upper reaches of the river always carries much more sediment than that coming from the Cretaceous black lands or even from the sandy lands of the Tertiary, though there is not a great amount from the sandy lands which finds its way into the Brazos above Jones Bridge.

The table below gives the results of silt measurements for the total time covered in this and previous printed reports:

Summary of silt measurements, Brazos River, Texas.

Time.	Total discharge.	Silt, one week's settlement.		Silt, one year's settlement.	
	Acre-feet.	*Acre-feet.*	*Per cent.*	*Acre-feet.*	*Per cent.*
August 1 to December 31, 1899	1,165,300	10,090	0.866	7,567	0.649
January 1 to December 31, 1900	8,806,986	115,782	1.315	86,837	.986
January 1 to December 31, 1901	976,602	12,328	1.262	9,246	.947
January 1 to December 31, 1902	3,362,991	40,190	1.195	30,142	.896
Total for 41 months	14,311,879	178,390	1.246	133,792	.935

This summary shows that the average percentage of silt found for 1902 is slightly smaller than the average found for the three years and five months during which systematic measurements have been conducted. The collections during 1902 were made at much shorter intervals, however, than those for the previous two years and five months, and it appears to the writer that if a mean value of 1.2 per cent at the end of one week's settlement, or 0.9 per cent at the end of one year be assumed, a very close approximation to general conditions will be obtained.

The importance of knowing approximately the percentage of silt carried by a given stream will be evident where storage reservoirs are contemplated. While it is not probable that such reservoirs will ever be constructed for irrigation purposes on the lower reaches of the Brazos, it is both possible and probable that this will eventually be done farther up, near the headwaters of the river, or on its branches. Also, in case an attempt is made in the future to open the river to navigation for any considerable portion of its length, it will be well to know something of the probable effect of silt upon the use of dams and locks. Futhermore, it is believed that the results obtained for the Brazos will be found to fairly represent the conditions which obtain in most of the streams within the borders of the State of Texas. It is true that two years' investigations on the Wichita River, at Wichita Falls, show somewhat higher results, but one of these years showed results almost identical with the mean given above. It should be remembered also that samples were not taken as frequently as would have been desirable. Moreover, the drainage area of the

Wichita River is quite small and the fall rapid, so that larger percentages of silt might naturally be expected.

RIO GRANDE.

Twenty-three samples of water from the Rio Grande, in eleven sets, had been collected under the direction of the consulting engineer of the International (Water) Boundary Commission at Courchesne's brickyard, about 4 miles above El Paso, during the year 1901, and were received too late for the results to be worked up in time for the 1901 report. The results found for these samples, and also for six samples collected at the same point during 1902, are given in the table below. The samples taken during 1901 cover a period of only four days about the middle of February and another period of eight days in May. The six samples collected during 1902 cover a period extending from April 26 to June 3. Whether or not these few samples represent the only periods during these years when the river carried any appreciable amount of sediment the writer is unable to say, but such would naturally be inferred. In a letter dated December 10, 1902, Mr. W. W. Follett, consulting engineer to the commission, says, in speaking of the year 1902: "I had no other samples taken. There has been practically no flow since June."

The discharges given in the fifth column of the following table were furnished by Mr. Follett, and from these and the mean percentage of silt in the samples collected at the same hour that the discharge measurements were made, the amounts of silt discharged, in cubic feet per second, were computed and entered in the sixth column. By reference to the 1901 report it will be seen that the percentages of silt in the samples collected during 1901, and 1902 while very high, are very much smaller than those found for the samples collected during 1900.

Silt determinations for the Rio Grande at El Paso, Tex.

When collected.	Silt in water at end of one week.				Discharge.	Total silt.	Appearance of water (color).	Time required to settle clear.
	Surface.	Mid depth.	Bottom.	Mean.				
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*		*Hours.*
1901.								
February 14, 9 a. m.	....	6.048	....	6.048	90	5.44	Chocolate	8.0
February 15, 12 m	....	5.864	....	5.864	110	6.45	....do	8.0
February 16, 7 a. m.	....	6.123	....	6.123	180	11.02	....do	8.0
February 16, 2 p. m.	....	5.920	....	5.920	180	10.66	....do	8.0
May 2, 10 a. m.	....	12.424	....	12.424	980	121.76	Dark chocolate	8.0
May 4, 10 a. m.	10.807	9.440	10.626	10.291	1,520	156.40	....do	8.0
May 5, 3 p. m.	6.499	5.710	6.006	6.072	1,520	92.28	Chocolate	5.5
May 6, 10 a. m.	5.403	7.055	5.581	6.013	2,380	143.10	....do	5.5
May 7, 9 a. m.	5.805	5.938	5.756	5.833	3,000	174.99	....do	5.5
May 8, 10 a. m.	6.512	5.540	5.460	5.837	3,100	180.95	....do	5.0
May 9, 9 a. m.	6.442	5.484	5.664	5.863	2,380	139.53	....do	5.0
1902.								
April 26	....	8.223	....	8.223	465	38.24	....do	4.0
April 28	....	13.550	....	13.550	441	59.75	Dark chocolate	4.0
April 30	....	5.452	....	5.452	145	7.90	Chocolate	4.0
May 2	....	6.807	....	6.807	64	4.36	....do	4.0
May 7	....	.399	....	.399	5	.02	Nearly clear	4.0
June 3	....	8.226	....	8.226	134	11.02	Dark chocolate	4.0
Mean	....	....	....	6.997	....	....	....	....

From May 4 to May 9, 1901, six sets of three samples each were taken and the means of the results obtained at different depths are as follows:

Percentages of silt at different depths.

	Per cent.
From top	6.911
From mid depth	6.528
From bottom	6.516
Mean	6.652

These results are similar to results found for the Brazos River, where the means for sets of three samples were taken. The largest mean percentage of silt occurred in samples taken at the top of the section and the smallest occurred in bottom samples. The mean percentage would appear to be carried a little above mid depth. The samples collected May 6 yielded about 1.5 per cent more sediment at mid depth than at either top or bottom, while the mid-depth sample on May 4 showed about 1.3 per cent less sediment than either the top or bottom sample. There was considerable variation in other sets also.

COLORADO RIVER AT WHARTON, TEX.

Gage-height observations were begun at Wharton on May 23, 1902, and were continued until September 30. The observer was also instructed to take daily samples of the river water, but was not as particular in this part of his work as was desirable. Some samples were lost by breakage, due to a runaway team, and no samples were taken after September 2. The following table gives the daily discharge of the river:

Daily discharge of the Colorado River at Wharton, Tex., 1902.

Day.	May.	June.	July.	Aug.	Sept.	Day.	May.	June.	July.	Aug.	Sept.
	Acre-ft.	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*		*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*	*Acre-ft.*
1	....	3,580	1,692	72,900	1,803	18	....	1,692	2,174	4,066	3,901
2	....	3,509	1,517	78,050	1,871	19	....	1,517	1,347	3,818	3,737
3	....	3,439	1,071	82,436	1,736	20	....	1,404	1,517	3,425	3,737
4	....	8,335	908	68,890	1,736	21	....	1,347	1,692	3,182	3,576
5	....	7,309	803	29,425	2,505	22	....	1,234	1,692	3,029	3,336
6	....	5,910	4,163	16,577	2,077	23	35,800	1,125	2,495	2,801	3,029
7	....	5,413	10,974	12,736	2,876	24	28,765	1,071	3,794	2,652	16,190
8	....	4,933	7,218	10,342	9,421	25	14,360	1,016	2,955	2,578	13,256
9	....	4,389	5,742	8,915	7,497	26	9,714	962	2,430	2,360	8,760
10	....	3,298	5,091	7,769	5,371	27	7,400	857	2,690	2,220	6,308
11	....	3,023	4,776	6,335	4,574	28	6,250	803	8,818	2,220	11,033
12	....	2,820	4,542	6,250	5,171	29	5,091	1,071	30,420	2,077	12,248
13	....	2,430	4,314	5,742	7,497	30	4,314	908	52,684	2,007	10,330
14	....	2,239	3,299	5,333	9,421	31	3,580	....	63,100	1,871	....
15	....	2,114	2,755	4,697	9,421						
16	....	1,871	2,366	4,318	5,371	Total	115,274	81,430	241,092	463,087	182,625
17	....	1,811	2,053	4,066	4,836						

The Colorado River did not overflow in the immediate vicinity of Wharton, but had done so considerably higher up the river, and as a

consequence the discharge diagram shown in fig. 12 presents characteristics similar to those exhibited for the Brazos at Richmond, though in a less marked degree as regards the length of time over which increase in discharge occurred. The falling off in discharge for one day was even greater, however, than was the case for the Brazos. This diagram, taken in connection with that for the Brazos at Richmond (fig. 13, p. 214), shows very clearly the difference in the amounts of water discharged by these two rivers. Stated numerically, the amount which passed Wharton during the months of June, July, August, and September was 968,234 acre-feet, as against 2,433,260 acre-feet passing Richmond during the same months, or slightly more

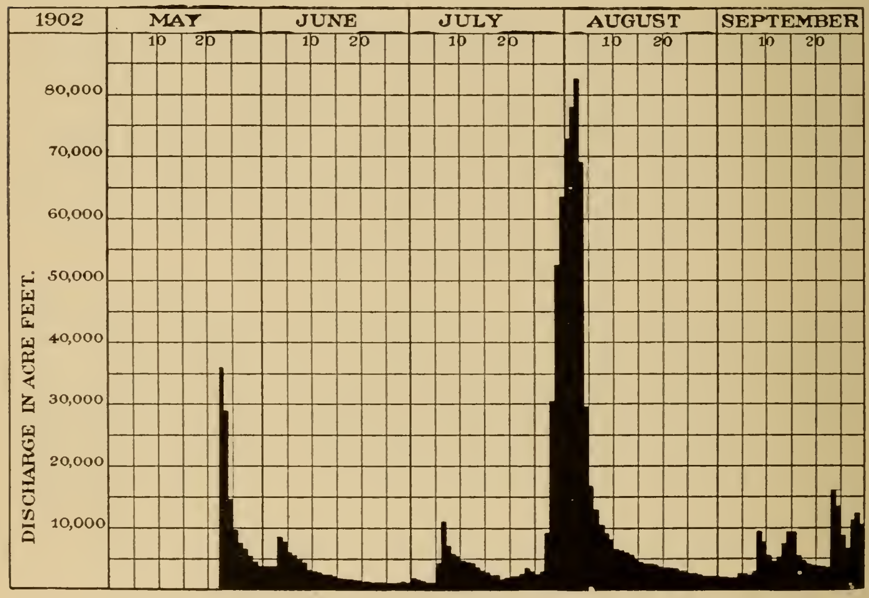


Fig. 12.—Diagram showing discharge of Colorado River at Wharton, Tex.

than two and one-half times as much water was discharged by the Brazos at Richmond as was discharged by the Colorado at Wharton. From June 14 to September 30, 1901, however, the total discharge of the Brazos at Richmond exceeded that of the Colorado at Wharton by only about 10,000 acre-feet. This was due to the fact that the Colorado watershed received considerably more rainfall—or at least yielded more run off—than did the Brazos watershed in 1901. There was quite a sharp rise in the Colorado during July which was not felt at all in the Brazos, and again in September the discharge in the Colorado considerably exceeded that of the Brazos.

Samples of water were taken in order to determine the percentage of silt carried by the Colorado River, but as has been stated the collections were not made with sufficient care. The results obtained are given in the following table:

Silt determinations for the Colorado River at Wharton, Tex., 1902.

When collected.	Silt in water.	Discharge.	Total silt.	Appearance of water (color).	Time required to settle clear.
1902.	*Per cent.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*		*Hours.*
June 1, 3, 4, 5, combined	0.750	2,639	19.8	Chocolate	....
June 7 to 11, inclusive	.594	2,123	12.6	.....do	....
June 15, 16, 18, combined	.258	944	2.4	Light red	....
July 3	.345	540	1.9	.....do	8.0
July 4	.262	458	1.2	.....do	8.0
July 5	.321	405	1.3	.....do	8.0
July 6	1.035	2,099	21.7	Red	8.0
July 7	1.319	5,533	73.0	.....do	8.0
July 8	.484	3,639	17.6	.....do	8.0
July 11	.420	2,408	10.1	.....do	8.0
July 12	1.438	2,290	32.9	.....do	8.0
July 15 to 20, inclusive	.059	1,178	.7	Nearly clear	....
July 29	1.573	15,337	241.3	Black	3.0
August 3	3.813	41,563	1,584.8	.....do	3.0
August 4	1.857	34,733	645.0	Dark red	8.0
August 5	2.500	14,835	371.0	.....do	2.0
August 6	2.070	8,357	173.0	.....do	2.5
August 7	3.247	6,421	209.0	.....do	5.0
August 8	1.749	5,214	91.2	.....do	4.0
August 9	2.581	4,495	116.0	.....do	4.0
August 12	2.273	3,151	71.6	.....do	4.0
August 13	1.281	2,895	37.1	.....do	4.0
August 14	.584	2,688	15.7	Red	5.0
August 15	.957	2,368	22.7	.....do	5.0
August 16	.816	2,177	17.8	.....do	5.0
August 17	.718	2,050	14.7	.....do	5.0
August 20	1.258	1,722	21.7	.....do	5.0
August 21	.935	1,604	15.0	.....do	5.0
August 23	.350	1,412	4.9	Nearly clear	....
August 24	.525	1,337	7.0	.....do	5.0
August 25	.156	1,300	2.0	.....do	5.0
August 26-31, inclusive	.010	1,072	1.1	.....do	....
September 1	.080	909	.7	.....do	....
September 2	.463	943	4.4	.....do	....
Mean of above percentages	1.091	....	....	....	....

In the table below are given the results of an attempt to approximate the total silt carried during the time in which samples were taken, but on account of the interpolations of percentages on days when no samples were taken this must be regarded as a very rough approximation.

Estimate of total silt carried by the Colorado River.

Time.	Discharge.	Silt.	
1902.	*Acre-feet.*	*Per cent.*	*Acre-feet.*
June 1–5	26,172	0.750	196.2
June 6–11	26,966	0.594	160.2
June 12–14	7,489	(0.400)	30.0
June 15–19	9,005	0.258	23.2
June 20–30	11,798	(0.200)	23.6
For month	81,430	0.533	433.2
July 1–3	4,280	0.345	14.8
July 4	908	0.262	2.3
July 5	803	0.321	2.6
July 6	4,163	1.035	43.1
July 7	10,974	1.319	144.7
July 8	7,218	0.484	34.9
July 9–10	10,833	(0.450)	48.7
July 11	4,776	0.420	20.1
July 12	4,542	1.438	65.3
July 13–14	7,613	(1.000)	76.1
July 15–20	12,212	0.059	7.2
July 21–28	26,566	(0.500)	132.8
July 29	30,420	1.573	478.5
July 30–31	115,784	(2.000)	2,315.7
For month	241,092	1.400	3,386.8
August 1–2	150,950	(2.800)	4,226.6
August 3	82,436	3.813	3,143.3
August 4	68,890	1.857	1,279.3
August 5	29,425	2.500	735.6
August 6	16,577	2.070	343.1
August 7	12,736	3.247	413.5
August 8	10,342	1.749	180.9
August 9	8,915	2.581	230.1
August 10–11	14,104	(2.300)	324.4
August 12	6,250	2.275	142.2
August 13	5,742	1.280	73.5
August 14	5,333	0.584	31.1
August 15	4,697	0.957	44.9
August 16	4,318	0.816	35.2
August 17	4,066	0.718	29.2
August 18–19	7,884	(1.000)	78.8
August 20	3,425	1.258	43.1
August 21	3,182	0.935	29.8
August 22	3,029	(0.600)	18.2
August 23	2,801	0.350	9.8
August 24	2,652	0.525	13.9
August 25	2,578	0.156	4.0
August 26–31	12,755	0.100	1.3
For month	463,087	2.469	11,431.8
September 1	1,803	0.080	1.4
September 2	1,871	0.463	8.7
For June, July, and August	785,609	1.942	15,251.9

In the foregoing table interpolated percentages are inclosed in parentheses, and while the number of such interpolations was not great they had to be made at the very times when daily samples were desirable. From July 30 to August 2, about one-third of the discharge during the period covered by the table passed the gaging station and on these days no samples were taken. The interpolated values may be considerably in excess of the true values, for from the samples taken it is evident that great variation in percentages occurred. The great differences in the percentages of silt shown in the samples collected on August 3 and 4 would seem to indicate that there was something wrong with one or the other of the samples, particularly since the sediment was quite dark—a condition which usually means lower percentages of silt, at least on the Brazos. Yet, in the absence of any definite means of determining which was wrong, the higher value was used in interpolating percentages for the preceding days for which samples were missing. The percentage 1.942 given for the three months, June, July, and August, was found by dividing the total silt, as found at the bottom of the last column, by the total discharge and then reducing the result to percentage. This value is high—higher than for the Brazos for the same months by about seven-tenths of 1 per cent. However, for the months of may, June, and July, the Brazos showed 1.719 per cent of silt in the water at the end of one week's settlement, which is not so very far behind the value given above for the Colorado during June, July, and August.

The watershed of the Colorado is largely made up of rocky slopes on the upper reaches of the river and one would naturally expect to find less sediment than in the Brazos water. It is thought, therefore, that the above results found from determinations made on samples collected near a slightly caving bank do not give a fair idea of the actual conditions existing even at times of abnormal discharge. They are instructive, however, as showing the effect of flood discharges on the relative quantities of silt carried during a given period of time.

Omitting the discharge for the month of June as having been incompletely obtained in 1901, a comparison of the discharges which took place during July, August, and September, 1901 and 1902, shows that 271,090 acre-feet were discharged in 1901 and 886,800 acre-feet in 1902. This latter is slightly more than three and one-fourth times the former. The discharge found for 1901 does not represent the minimum summer discharge because of the relatively sharp rise which occurred in July and the second rise in September, but the low discharges occurring during the first half of July do, very likely, represent the minimum discharge for as much as half a month—or at least something very close to it.

COMPARISON OF SILT DETERMINATIONS BY VOLUME AND BY WEIGHT.

Following the method described in the 1901 report, experiments were continued during 1902 with the purpose of ascertaining the relation between the percentage of silt found volumetrically and that found by weighing the dried sediment. The determinations by weight which are included in this report were made by Dr. N. Fraenkel, assistant chemist in the Texas experiment station. Where a set was made up of more than one sample an equal amount was taken from each sample in the set, and these were thoroughly combined before filtering a measured quantity of the water through a Gooch crucible. The sediment remaining after having filtered the water until the effluent was clear was dried and then weighed. For the Brazos River only three such determinations were made in 1902, while for the Rio Grande ten such determinations were made for samples collected in 1901 and six determinations for samples collected in 1902. The table given below shows the results of these determinations and the relative volumes, or ratios, of percentages as determined volumetrically after one week's settlement compared with the percentage of silt to water when determined by weight.

Comparison of sediment determinations by volume and by weight.

Where and when collected.	By volume, end of one week.	By weight.	Ratio.
Brazos River at Jones Bridge:	*Per cent.*	*Per cent.*	
Apr. 10, 1902	2.469	0.8810	2.802
Apr. 13, 1902	1.214	.3845	3.157
Apr. 16, 1902 (average of 2 of the 3 samples taken on that date)	2.439	.9595	2.542
Mean for above 3 sets	2.041	.7417	2.752
Mean for 9 sets in 1901 [a]	1.900	.6170	3.080
Mean for samples investigated, 1901 and 1902	1.935	.6481	2.986
Rio Grande at El Paso:			
Feb. 14, 1901	6.048	1.3600	4.447
Feb. 15, 1901	5.864	1.4720	3.984
Feb. 16, 1901 (2 samples)	6.022	1.4720	4.091
May 2, 1901	12.424	3.9800	3.122
May 4, 1901	10.291	2.9625	3.474
May 5, 1901	6.072	1.9200	3.163
May 6, 1901	6.013	2.0250	2.970
May 7, 1901	5.833	1.9500	2.992
May 8, 1901	5.837	1.9900	2.933
May 9, 1901	5.863	1.6400	3.573
Mean for above 10 sets in 1901	7.027	2.0772	3.383
Apr. 26, 1902	8.223	1.5620	5.264
Apr. 28, 1902	13.550	3.6100	3.753
Apr. 30, 1902	5.452	1.3500	4.039
May 2, 1902	6.807	2.0575	3.309
May 7, 1902	.399	.0630	6.333
June 3, 1902	8.226	2.4590	3.345
Mean for above 6 sets in 1902	7.110	1.8503	3.843
Mean for 10 sets in 1901	7.027	2.0772	3.388
Mean for 8 sets in 1900 [a]	18.310	4.9460	3.702
Mean for samples investigated, 1900, 1901, and 1902	10.808	2.9760	3.632

[a] See U. S. Dept. Agr., Office of Experiment Stations Bul. 119.

Combining the results for all samples so far investigated, we have for the ratios of percentages by volume to those found by weight:

Ratio of percentage of silt by volume to those by weight at end of one week.

For the Brazos	2.986
For the Rio Grande	3.632

If we reduce the percentages obtained volumetrically by one-fourth to find the probable relation after one year's settlement has taken place, there results:

Ratio of percentage of silt by volume to those by weight at end of one year.

For the Brazos	2.240
For the Rio Grande	2.724

To include all investigations of this character so far made under direction of the writer, it may be well to quote from the report for 1901 that the Wichita River showed the ratios 2.210 and 1.660 for one week's and one year's settlement, respectively.

From these results it will be seen that to determine the percentage of silt by weight and then to attempt to get the relative volumes of water and silt by multiplying the weight of the dried sediment by the

percentage found will, at least in the cases investigated, except possibly the Wichita River, give results which indicate a smaller total volume of sediment than actually exists, even at the end of one year.

DUTY OF BRAZOS RIVER AT RICHMOND, TEX., IN RICE IRRIGATION.

Daily gage heights were taken at the Southern Pacific Railway bridge across the Brazos at Richmond during the months of June, July, August, and September, 1902, in order to obtain further information regarding the flow in this river during the season of rice irrigation in addition to that which the measurements during 1901 furnished. However, the discharge during 1902 was at no time as low as during 1901. On only two days, July 19 and 20, did the discharge fall below 1,200 cubic feet per second in 1902, and on these days the discharge averaged a little under 1,000 cubic feet per second. For the first week in August, 1901, the daily discharge was less than 750 cubic feet per second and on one day it fell almost to 700 cubic feet per second. During the first half of August, 1902, the lowest average daily discharge was not as low as 5,000 cubic feet per second. In fact, it was during this time and the last five days of July that the water which had flooded the bottom lands from the neighborhood of Hempstead as far north as Marlin was passing Richmond. While the river rose dangerously near the overflow point, it did not get out of banks at Richmond. Below will be found the table of daily discharges:

Daily discharge of the Brazos River at Richmond, Tex., 1902.

Day.	June.	July.	August.	September.	Day.	June.	July.	August.	September.
	Acre-ft.	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*		*Acre-ft.*	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*
1	14,986	3,092	104,960	5,317	18	4,483	2,430	15,990	9,929
2	14,283	2,618	110,780	5,210	19	3,876	1,882	14,422	8,947
3	13,318	2,523	114,430	5,210	20	3,481	1,972	12,641	7,997
4	11,714	3,578	120,490	5,000	21	3,285	2,339	11,326	7,648
5	9,928	3,677	128,450	5,105	22	3,190	3,776	10,340	7,301
6	8,231	4,380	138,010	5,318	23	2,711	4,187	9,266	7,075
7	10,430	3,876	142,880	5,530	24	2,711	4,586	8,350	6,848
8	11,715	3,382	144,370	5,423	25	2,711	4,483	7,648	6,625
9	12,775	2,902	135,570	5,318	26	2,523	9,189	6,849	5,962
10	12,775	2,523	99,740	7,075	27	3,382	25,506	6,401	6,401
11	11,454	2,711	56,480	7,531	28	3,872	50,380	5,962	6,512
12	9,680	3,092	38,485	7,531	29	4,483	72,020	5,962	8,708
13	7,997	3,382	31,440	7,763	30	3,092	82,510	5,746	9,682
14	7,074	3,876	26,720	7,997	31	....	97,420	5,530	....
15	5,962	3,382	23,638	10,176					
16	5,317	2,997	20,700	11,455	Total	216,544	417,289	1,581,638	217,789
17	5,105	2,618	18,062	11,195					

These discharges, when compared with those for the corresponding months of 1901, will illustrate how different the discharge may be on different years. The year 1901 was very dry, but so also was 1902 up to about the last week in July. Counting from the 14th of June to the 30th of September, about 315,200 acre-feet of water passed Richmond in 1901, and about 2,284,000 acre-feet in 1902, or a little more than seven times as much during the latter year as during the former.

If we exclude the month of June from both years, we have for the months of July, August, and September the following total discharges: In 1901 about 203,400 acre-feet, and in 1902 about 2,216,700 acre-feet, or nearly eleven times as much during the latter year. These two years, therefore, represent entirely different conditions. When com-

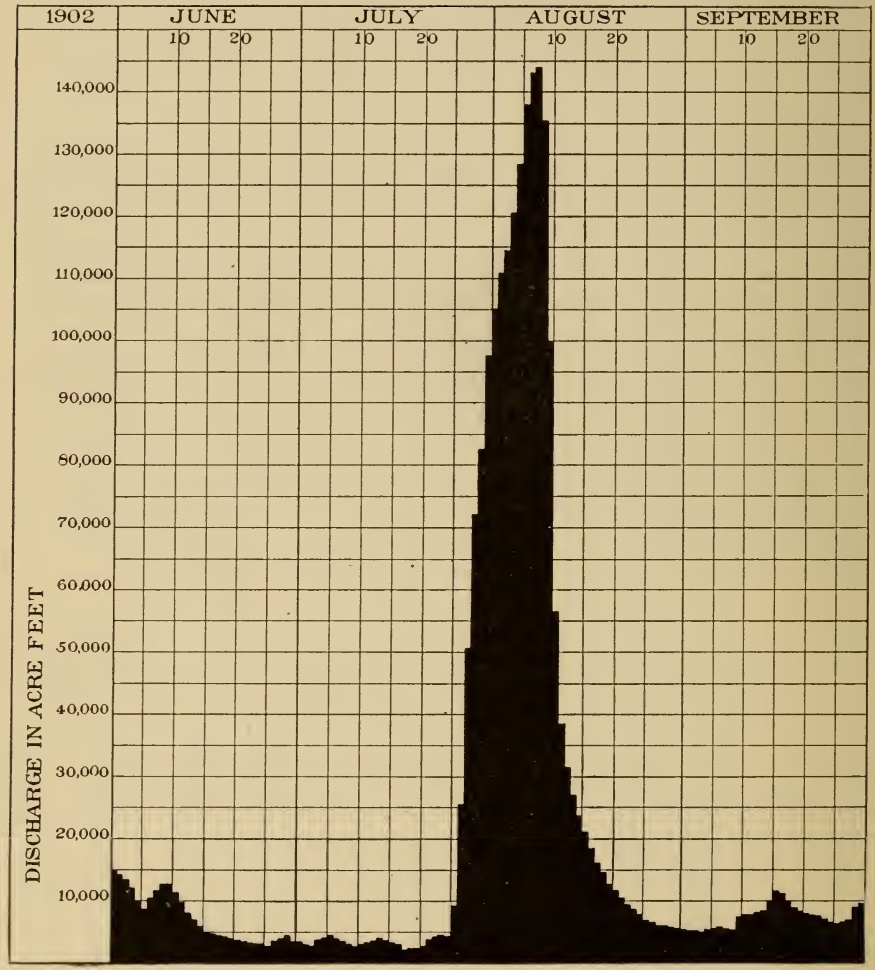


FIG. 13.—Diagram showing discharge of Brazos River at Richmond, Tex.

pared with the conditions existing during the summer of 1899, the year 1902 can not be considered one of maximum summer discharge.

Fig. 13 shows, in geographical form, the variations in daily discharge, and is interesting as showing the effect of overflows higher up the river upon the rate of increase in discharge. Usually the rising side of the diagram is abrupt, and the falling side much more gradual,

but here the case is exactly reversed, as was also the case, though in a much less marked degree, for the Jones Bridge station. While the waters were spreading out over the bottom lands higher up the river, the rate of increase in discharge at Richmond was small, and as these overflowing waters returned to the channel higher up the discharge at Richmond continued to increase. After the crest was reached, however, the fall was surprisingly rapid until the river was less than half bank full, after which the fall became much more gradual. During the months of June, July, August, and September the amount of water passing the Richmond station was in excess of the measured portion which passed Jones Bridge by nearly two-fifths of the latter amount, the totals for these months being, for Richmond, 2,433,260 acre-feet, and for Jones Bridge, 1,734,630 acre-feet. This difference is probably due not only to the large amount of water from Navasota River, the Yegua, and smaller streams which empty into the Brazos between the two stations, but also to the unmeasured flood water which left the channel above Jones Bridge and returned to it lower down the river. This was probably but a comparatively small part of the difference, the bulk of it being due to the Navasota.

In the 1901 report some computations upon the probable acreage which could be watered by the discharge through the Richmond station, or rather by the minimum discharge, were made; but it was stated that the duty of water assumed, namely, 7 gallons per acre per minute, was about the most favorable assumed by engineers and irrigators in the rice sections west of Houston, and that the actual duty appeared to be unknown. Bulletin No. 113, Office of Experiment Stations, United States Department of Agriculture, gives the results of duty measurements by Mr. Frank Bond, at Raywood, Tex., and Crowley, La., for the summer of 1901. From the results given by Mr. Bond, page 23, we get, after converting his results into the awkward unit used by irrigators west of Houston, the following results for the Raywood measurements:

	Gallons per acre per minute.
Amount supplied to rice field by canal (nearly)	5.25
Amount of rainfall (nearly)	2.45
Total water supplied to field	7.7
Evaporation	4.25
Net amount of water utilized	3.45

The net depth of water actually utilized at Raywood was, by Mr. Bond's measurements, 12.78 inches, and that similarly utilized at Crowley 12.04 inches—a very close agreement. The amount supplied from the canal at Raywood, however, was nearly one-fifth more than that supplied at Crowley, while the rainfall was nearly one-tenth less.

and the evaporation a little more than one-tenth greater. Nothing short of actual duty measurements will show exactly what amount of water would be required to mature a good rice crop west of Houston; but, for the sake of getting at some approximation to the probable quantity, let us assume that the increase in evaporation along the Brazos or Colorado River would equal the increase at Raywood over Crowley, and let us assume that the rainfall would decrease in the same ratio (the decrease is probably greater, as regards the Colorado at least), and let us also assume that the same net quantity of water is required in the Brazos and Colorado belt as is required at Raywood, and we shall have the following results:

	Inches.
Net depth of water to be actually utilized	12.78
Probable evaporation from surface of field	17.59
Total depth of water required	30.37
Probable depth of rainfall	8.26
Net depth of water to be supplied by irrigation	22.11

Now, if this be supplied in the same time as at Raywood (seventy-one days) there will have to be supplied from the canal 5.9 gallons per acre per minute—say 6 gallons. What the loss in evaporation and seepage from the main canal itself will be will depend upon the length of the canal and the character of construction. On the whole, it does not appear that the estimate of 7 gallons per acre per minute should be reduced in figuring the acreage which will be served in very dry seasons, such as was the summer of 1901. However, the majority of seasons will very probably be much more favorable than was that of 1901, and if the loss of an occasional crop—or partial loss—is permissible, the acreage estimated for extreme low-water stage in 1901, namely, 45,000 acres, may be increased. Suppose we increase it by two-thirds of itself. We shall then have 75,000 acres as the greatest area that the discharge at Richmond should be expected to water, even supposing that all the water may be drawn from the river when needed. If the stream is ever opened for navigation, of course, this can not be done. Moreover, if pumping plants are located near the mouth of the river there will be danger from salt water working its way back from the Gulf in case of total withdrawal of the low-stage flow from the river.

Near Fulshear, about 15 miles above Richmond, and near Duke, about the same distance below Richmond, large irrigation systems are already in partial operation. The writer has been given to understand that the originators of the Fulshear system contemplate watering about 150,000 acres from their plant eventually, though the canal and plant as now installed will fall far short of even the third of this.

DUTY OF COLORADO RIVER IN RICE IRRIGATION.

Assuming that the computations made under the head of the Brazos River at Richmond, regarding the probable duty of water in the rice belt west of Houston, hold for the Colorado region, and referring to the discharge measurements given on page 207, there appears to be no good reason to materially modify the tentative computations made on the acreage that can be served by the Colorado at seasons of extreme low water. If, however, the loss, or partial loss, of an occasional crop be permitted, we will assume that the acreages given for 1901 may be increased two-thirds. This, for the discharge found for the first half of July, 1901, would allow for an acreage of 60,000 acres being served by the discharge at Wharton, while for the month beginning August 16 and ending September 15, 1901, the acreage, similarly increased, would amount to about 67,000 acres that the Wharton discharge might be counted on as capable of serving.

IRRIGATION EXPERIMENTS AT THE MISSOURI EXPERIMENT STATION.

By H. J. Waters,

Dean of the College of Agriculture and Mechanic Arts, University of Missouri, and Director of the Missouri Agricultural Experiment Station.

INTRODUCTION.

Experiments in irrigating apples, strawberries, and nursery stock were conducted in the summer of 1901 and continued in 1902 by the Missouri Experiment Station in cooperation with the Office of Experiment Stations of the United States Department of Agriculture, by Mr. W. L. Howard, assistant horticulturist at the Missouri Station. The report of these experiments for 1901 was published last year.[a] In that report it was shown that the season of 1901 was unusually dry and hot and that plants and trees were watered, but too late in the season to affect the crop for that year. The application of water did, however, produce a considerable growth of plants, and it was pointed out that this growth would probably have a beneficial effect upon the crop for the season of 1902.

The report for 1901 showed that the precipitation from April 7 to October 31 of that year was 10.8 inches only 39 per cent of the normal, or a deficiency of 16.57 inches. The following table gives the meteorological data from November 1, 1901, to June 30, 1902:

Weather conditions at Columbia, Mo.

Date.	Temperature.						Precipitation.	
	Maximum.		Minimum.		Mean.	Departure from normal.	Rainfall.	Departure from normal.
1901.	*Day.*	*°F.*	*Day.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*
November	11	75	13	17	42.4	−0.6	8.00	−1.56
December	12	62	20	−23	29.6	−8.1	2.29	+ .56
1902.								
January	9	63	27	− 9	29.2	−1.8	1.40	−1.13
February	26	60	3	−11	22.1	−8.9	.90	−1.42
March	26	74	17	12	44.4	+2.9	3.58	+ .51
April	20	88	8	26	53.1	−3.0	3.42	− .19
May	20	92	28	46	68.8	+4.4	4.33	− .55
June	11	94	22	43	69.8	−4.9	6.56	+1.78

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 119, pp. 305–311.

IRRIGATION OF STRAWBERRIES.

The season of 1901 was very disastrous to strawberry plants, many of the old plants dying and practically no runners being formed under ordinary treatment. The irrigated plants developed strong crowns, and undoubtedly stored an abundant supply of food for the next year's crop (Pl. XI).

At the beginning of the winter of 1901, when the ground was first firmly frozen, the strawberry plants were mulched to a depth of 5 or 6 inches with wheat straw. This is the customary winter treatment for strawberries where they are well cared for. The entire field, both the irrigated and nonirrigated, was covered with straw, which was allowed to remain, according to common practice, until after the fruiting season the following summer.

In the spring, on account of the mulch, there was no cultivation, and no irrigating was done this year. During the early spring the season was dry, but in both the experimental plats the plants began growth as under normal conditions, there being no apparent differences in the time of starting between those under different treatment. It will be seen from the meteorological table that the rainfall for both April and May was below the normal, although in March there was one-half inch above the normal, but the soil was still greatly deficient in moisture. During the first week in April, just at the flowering time, there was a shower amounting to 0.6 inch, which greatly enlivened the plants temporarily and was no doubt a potent influence in causing more perfect pollination on account of the additional vigor infused into the plants. The majority of the fruit began to ripen about May 20, but the fruiting season, when well advanced, was prolonged by a heavy rain on June 1. This rain was the heaviest that had fallen for a year and the soil was thoroughly saturated to a depth of several inches. The following is a record of the berry harvest:

Yield of strawberries on irrigated and unirrigated plats.

Variety.	Treatment.	First ripe fruit.	Last ripe fruit.	Crates per acre.	Value.	Percentage of increase due to irrigation.	Value due to irrigation.
						Per cent.	
Gandy	Irrigated	May 30	June 14	276.7	$484.22	874	$434.52
	Check	May 28	....do...	28.4	49.70		
Bubach	Irrigated	May 21	June 9	233.9	419.32	723	369.62
	Check	....do...	June 2	28.4	49.70		
Clyde	Irrigated	May 20	June 9	229.1	401.92	477	332.45
	Check	....do...	June 7	39.7	69.47		
Aroma	Irrigated	May 23	June 9	290.6	508.55	628	439.73
	Check	....do...	June 7	39.9	68.82		
Ridgeway	Irrigated	....do...	June 11	367.8	643.65	151	387.63
	Check	....do...	....do..	146.3	256.02		

A fact not shown by the above data is that with a few of the varieties the watering seemed to have a tendency to cause them to be a day

or two later in coming into ripening in marketable quantities, but this drawback was more than offset by their longer period of fruiting. The check rows continued to ripen fruit until the dates indicated, but for several days toward the last it was of a very poor grade, many of the berries being so small and hard as to be unmarketable. With all of the varieties in the test the check rows reached their greatest period of fruitfulness from one to two days earlier than those irrigated, but when the irrigated ones did arrive at the height of their ripening they did not decline nearly so quickly.

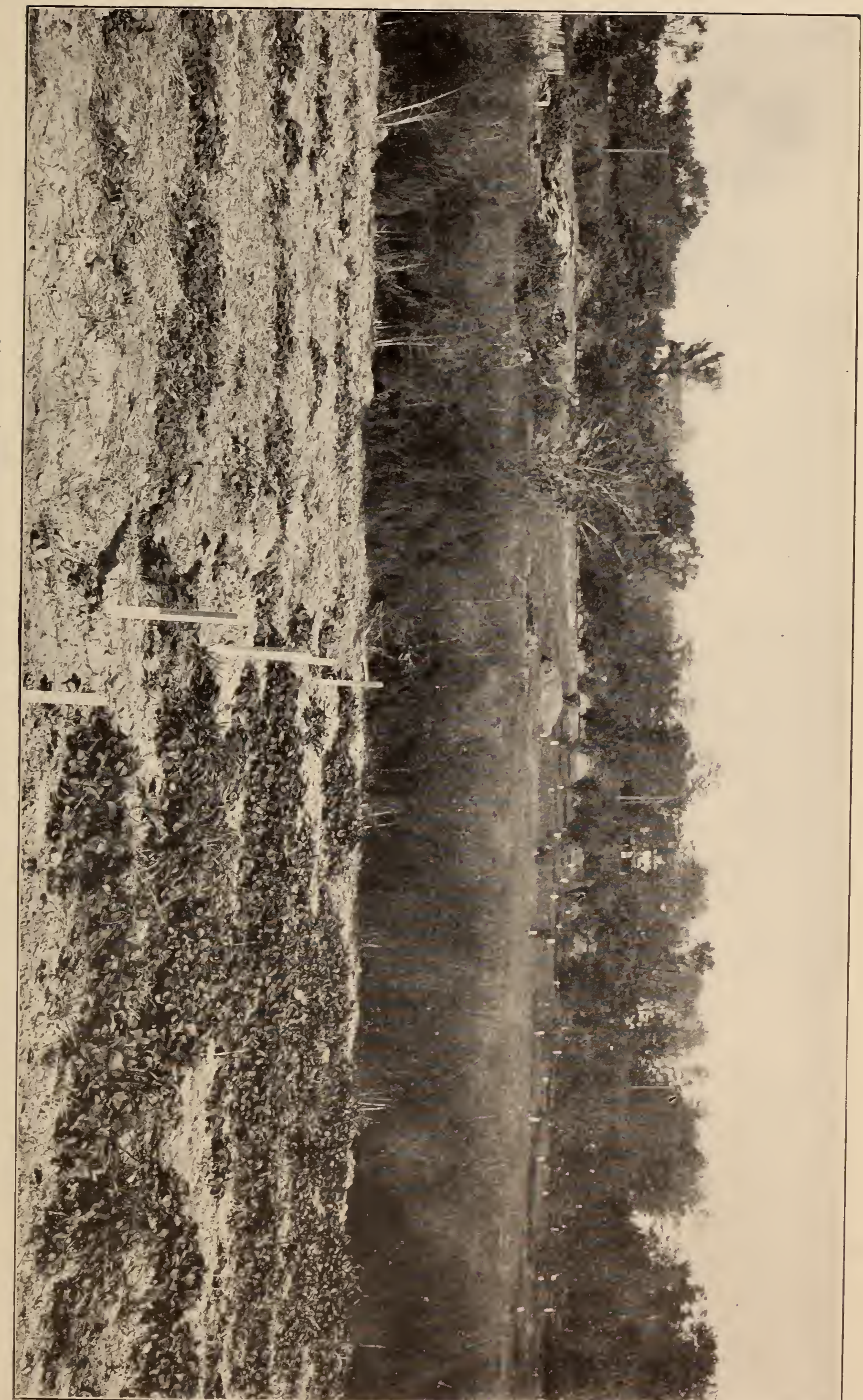
On the check rows all of the fruit ripened early and nearly all was harvested with one or two pickings, while the watered ones, although starting a day or two later, prolonged their fruiting period over several days, thus permitting the product to be picked, packed, and marketed to good advantage.

The most marked feature of the data in the tabulated statement above is the enormous percentage of increase in the amount of fruit produced due to irrigation. The five varieties represented are all of commercial importance in Missouri. The test shows that the Gandy is influenced very greatly by the amount of moisture available, having made an increase of 874 per cent in yield, valued at $434.52 per acre, where irrigated. While the Ridgeway is much better able to withstand a drought, yet it produced 151 per cent more fruit, worth $387.63 per acre, by watering. This is concrete evidence of the value of irrigating strawberries in a dry season to promote the growth and development of the plants preparatory to the production of a crop the following spring.

IRRIGATION OF BEARING APPLE ORCHARDS.

Twenty-four young, vigorous apple trees just coming into bearing were included in the test, and embraced the following standard varieties: Ben Davis, Gano, Jonathan, Missouri Pippin, and Jeniton. They were in rows 25 feet apart each way, on strong land, had been given excellent cultivation ever since they were set out, and were in a vigorous, thrifty condition. In choosing the trees for experiment, they were arranged in pairs, having the two trees of each pair as nearly alike in size, form, vigor, quantity and quality of fruit set as possible, one of which was irrigated and the other left as a check. Care was taken to have the irrigated tree far enough away from the check tree to avoid any effect of the water on the unirrigated tree. The only observed difference between the irrigated and unirrigated trees in the season of 1901 was that the irrigated trees retained their leaves a little longer than those not irrigated.

None of the bearing apple trees under experiment, either irrigated or unirrigated, were injured by the winter. In the spring there was no noticeable difference between the two lots in the time growth began.



VIEW OF IRRIGATED AND UNIRRIGATED PLATS OF STRAWBERRIES, COLUMBIA, MO.

Also, in so far as could be determined from careful observation, the irrigating did not exert any appreciable influence on either the quantity or the quality of the fruit crop.

A probable explanation for the seeming small influence of the watering on the trees lies in the fact that these were vigorous young trees growing on a stiff clay soil which, when properly cultivated, as this was, retains its moisture well even during severely dry weather. During the summer of 1901, all through the severe drought, the soil was kept finely pulverized at the surface by cultivating after each light shower with an Acme harrow, and under this treatment there was no time during the summer when moisture could not be readily found at a depth of only 3 or 4 inches beneath the surface. Had this ground been indifferently cultivated or not stirred at all during the dry season there can be no doubt that the lack of water would have exerted a much greater influence than it did.

IRRIGATION OF NURSERY STOCK.

Most of the crop in this nursery consisted of apple trees grown from grafts planted in the spring. Nine varieties of apples were represented in the planting. The rows were 4 feet apart and the plants from 8 to 12 inches apart in the rows. In the middle of the nursery a block was marked off to be irrigated. This plat extended across 28 rows, included all of the varieties, and represented an average of soil conditions and growth of the field. Adjoining both ends of this block were check plats of unirrigated stock. The report for 1901 shows that the irrigated stock made a much larger growth than the unirrigated, the growing season being prolonged by the use of water.

By reference to the meteorological data on page 218 it will be seen that on the 20th of December, before all of the plants had shed their leaves, there was a temperature of 23 degrees below zero, the coldest weather of the winter. According to all theories this should have killed all of the nursery stock which had been caused to prolong its growth until caught by the severe cold, but such was not the case.

In the spring, when growth began, careful observations were made throughout the nursery in order to compare the results of the winter on the irrigated and unirrigated trees, with the result that it was found that those which had been watered were even less injured than those in the check plats, neither being seriously winterkilled. Interested visitors still freely predicted that the irrigated stock would make inferior trees, saying that they would surely be "black at the heart," a condition sometimes resulting from winter injury in the nursery. Such trees do not grow well after being planted. The irrigated trees, however, continued to grow satisfactorily throughout the season of 1902 and made most excellent trees of fancy grade in size and perfection in shape.

The experiment with this crop fully demonstrated that in a dry season, if water facilities can be provided at a reasonable outlay, it is a good investment to irrigate young nursery apple stock during the first year of its growth from the grafts.

IRRIGATION OF ASPARAGUS.

In the spring of 1901 the asparagus field was irrigated. This crop is grown in rows 4½ feet apart, and was planted in the spring of 1897, the plants thus having had four seasons' growth, and were in prime condition as to vigor.

Beginning May 18 water was applied by allowing it to run down single furrows between the rows. On the 20th and 21st more water was applied until the soil was thoroughly saturated down to a depth of more than a foot. This crop was not irrigated again and no differences in appearance were apparent during that season between the irrigated and unirrigated parts of the field.

For the season of 1902 only incomplete data are available. The following is a record of the yield after the first two weeks' cuttings had been going on, that is from May 2 to 31:

Yield of asparagus under irrigation.

Variety.	Treatment.	Number of pounds per acre.	Value.	Increase.	
				Percentage.	Value.
Palmetto	Irrigated	2,602	$390.30	23	$73.35
	Check	2,113	316.95		

The yield was increased 23 per cent by saturating the soil once a year before harvesting. Moreover, the stalks cut from the irrigated section began growing earlier in the spring, were uniformly larger, more symmetrical, and altogether a higher grade of asparagus than the product from the unirrigated rows. To a high-class gardener this fact is of even more importance than increase in yield, as special markets are much sought for and highly prized.

The test shows the possibilities in the way of influencing the growth of asparagus by watering, and this knowledge will be of great value to the market gardeners of the country.

IRRIGATION IN WISCONSIN IN 1902.

By A. R. Whitson.

INTRODUCTION.

Studies on the relation of crop production to amount of water used and on the expense of applying water have been made on heavy clay loam soil at Madison and on very sandy soil at Stevens Point. The unusually large precipitation of the season made it impossible to add water by irrigation on the land at Madison without the certainty of injuring all crops except hay, but at the same time allowed us to study the effects of previous irrigation on the soil.

The rainfall was less during the latter part of the season at Stevens Point than at Madison and the lighter character of the soil allowed it to dry more rapidly, so that irrigation was helpful to a limited extent. To serve as a basis of estimating the necessity or benefits of irrigation through a number of years the rainfall during the six months, April to September, is given in ten-day periods for the past twenty-one years at Madison, and for the past six years at Stevens Point.

Rainfall in ten-day periods from April to September, inclusive, for the years 1882 to 1902, at Madison.

Date.	1882.	1883.	1884.	1885.	1886	1887.	1888.	1889.	1890.	1891.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Apr. 1-10	2.51	....	1.24	0.99	0.12	0.00	1.28	0.19	1.03	0.38
Apr. 11-20	1.44	....	2.56	1.49	1.00	.20	.15	1.06	1.13	.54
Apr. 21-30	.26	....	.71	.97	1.52	.80	.92	.46	.06	.53
May 1-10	1.19	1.31	3.11	.34	1.48	.99	1.53	.45	3.01	.07
May 11-20	.91	3.02	.25	.36	.53	.55	1.46	1.42	1.23	.00
May 21-30	.34	2.65	.85	.98	.01	.43	.67	1.14	.79	1.33
May 31-June 9	2.04	5.03	1.52	3.54	.49	.24	.00	.69	3.26	1.23
June 10-19	1.15	2.09	1.21	.54	.30	.57	2.21	1.14	2.52	.77
June 20-29	2.95	.45	1.84	1.03	.29	.06	.64	.17	1.69	1.70
June 30-July 9	4.17	1.78	3.02	2.16	.41	4.26	1.24	.51	.47	1.85
July 10-19	.05	2.26	.21	1.74	.14	1.11	.17	.49	.81	.02
July 20-29	.01	4.85	5.15	3.37	.24	.27	.72	1.12	.78	.80
July 30-Aug. 8	2.60	.40	1.52	2.80	.38	.23	.74	.55	1.50	.18
Aug. 9-18	3.57	.37	.72	.64	3.36	3.09	.39	.05	1.11	.19
Aug. 19-28	.05	1.97	1.91	2.70	1.23	.66	.27	.12	1.62	.76
Aug. 29-Sept. 7	2.41	.93	2.32	.34	.27	3.84	.20	1.32	1.01	.29
Sept. 8-17	.53	.54	1.37	3.24	.76	1.24	.56	.38	.38	.00
Sept. 18-27	.06	.92	.51	.22	1.34	1.26	.28	.23	.23	.00

Rainfall in ten-day periods from April to September, inclusive, for the years 1882 to 1902, at Madison—Continued.

Date.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Apr. 1-10	2.07	1.02	0.81	1.06	0.69	0.27	0.21	0.10	0.00	0.33	0.19
Apr. 11-20	.48	2.21	.98	.00	2.19	.81	1.61	.06	1.37	.12	.43
Apr. 21-30	1.39	1.30	1.83	.00	.56	1.42	.56	2.54	.00	.00	.55
May 1-10	3.95	1.12	1.57	1.31	1.30	.28	1.41	1.05	.91	.89	1.97
May 11-20	1.31	.30	1.42	.91	2.56	.32	2.55	1.01	.82	.05	1.47
May 21-30	.79	.62	.42	.38	2.26	.14	.75	2.72	.13	1.43	1.72
May 31-June 9	3.93	1.61	.00	.26	.93	.79	.11	1.03	.76	.16	1.18
June 10-19	2.64	4.31	1.83	.21	.84	1.29	1.58	1.16	1.07	1.97	1.39
June 20-29	2.00	1.01	2.11	.27	.82	1.95	2.87	.15	1.37	.29	1.28
June 30-July 9	1.01	2.77	.00	.02	.77	.65	.29	2.54	2.74	.12	4.31
July 10-19	.15	1.64	2.04	.55	.41	.46	2.55	.48	2.92	.41	2.28
July 20-29	.96	.23	.31	.46	2.39	.67	.10	.24	1.45	1.07	2.41
July 30-Aug. 8	.51	.04	.25	.07	.27	.82	.95	2.16	.10	.00	.42
Aug. 9-18	.24	1.38	.65	.01	1.25	.70	1.20	.37	.75	.85	.58
Aug. 19-28	2.84	.00	.00	1.54	.96	.32	.44	1.01	1.76	.52	.07
Aug. 29-Sept. 7	.76	.00	1.62	.08	.40	.68	.49	.30	.09	.00	1.25
Sept. 8-17	2.51	.00	2.30	.35	2.07	1.67	1.02	.46	.62	3.43	.02
Sept. 18-27	.01	1.07	.00	.01	1.01	.00	.04	2.65	.79	.00	.18

Rainfall for ten-day periods at Stevens Point, Wis.

Date.	1897.	1898.	1899.	1900.	1901.	1902.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Apr. 1-10	0.33	0.13	0.00	0.00	0.00	0.30
Apr. 11-20	1.30	1.21	1.15	2.73	.90	.00
Apr. 21-30	.49	.00	2.71	.31	.00	1.29
May 1-10	.41	.47	.37	.15	.33	3.87
May 11-20	1.57	1.02	.00	1.74	.00	2.70
May 21-30	.41	.81	.18	.00	1.71	2.31
May 31-June 9	2.02	.00	2.39	.23	.73	1.39
June 10-19	2.08	2.27	3.56	.08	.89	.16
June 20-29	2.61	2.89	.53	.20	1.25	1.61
June 30-July 9	.09	.16	.80	2.65	2.35	.86
July 10-19	1.59	.00	2.43	3.02	.38	.56
July 20-29	1.33	.02	.00	1.00	1.32	1.71
July 30-Aug. 8	.78	2.84	.00	.00	.00	.91
Aug. 9-18	.63	1.66	.51	1.15	.65	.45
Aug. 19-28	.27	.00	1.63	.17	.74	.00
Aug. 29-Sept. 7	.87	.44	2.10	2.39	.05	2.98
Sept. 8-17	1.90	.00	.15	2.83	2.72	.44
Sept. 18-27	.00	1.45	.00	3.95	.42	.88

WORK AT MADISON.

As previously stated the rainfall was such as to make the irrigation of tilled crops unnecessary, and so give opportunity to determine the effects of previous irrigation. Irrigation has been practiced on plats, all but one of which are in a four-year rotation of oats seeded to clover, potatoes on manured clover sod, and, lastly, corn. The first two crops are all irrigated when necessary, while a part of the last two are left unirrigated for the purpose of determining the effect of the irrigation. One plat has grown corn for nine years without the addition of fertilizer after the first year till this year when part of the field was manured.

It will thus be seen that on the ground in a crop rotation part of the soil is thoroughly watered either by rain or by irrigation every year, while the other part is left dry half of the time, when rainfall is defi-

cient. Observations were made this year to determine whether the heavier crops removed from the irrigated ground during the past years had reduced the fertility of the soil below that of the soil not irrigated.

Where the rotation of crops and manuring was followed no difference in the fertility of the soil could be detected either in the yield of stalks or grain, in the case of corn, or of potatoes. Indeed the yield of corn this year, 66.8 bushels to the acre, has been greater than for any year past, and the yield of potatoes, 309.1 bushels of large potatoes, is larger than the average of the past six years, 301.7 bushels, although considerably less than that of 1901, 361.2 bushels, probably on account of the colder weather and less sunshine of this season.

It would seem, therefore, that there is little reason to fear injurious effects of irrigation on the fertility of land of this character and topographical position when moderately fertilized and kept in good rotation.

The plat which has been cropped to corn for eight consecutive years without fertilization after the first year till this year, when part of the field was manured, does, however, show the effects of irrigation. The same portions of the field have been irrigated each year. The average amount of water added by irrigation has been 5 inches each season for the past eight years, but in 1901 8 inches were used. This year, 1902, when, on account of the abundant rainfall, no water was added, the difference between the subplats which had been irrigated and those which had not was very noticeable. The irrigated plats were lighter in color and not so thrifty, and the addition of manure did not reduce the difference, but rather increased it, as shown in the following table:

Yield of silage per acre in 1902 on ground part of which had been and part of which had not been irrigated in previous years.

	Manured in 1902.	Not manured.
	Tons.	*Tons.*
Irrigated previous to 1902	13.581	11.524
Not irrigated at any time	16.010	12.358

This difference may be due to either or both of two causes—to the reduced fertility produced by the growth of larger crops on the irrigated ground during dry seasons or to leaching of the soil by irrigation water. As it is unlikely that any appreciable amount of leaching has been caused by irrigation of this clay loam, with the moderate quantities of water used, it seems to the writer probable that the reduced yield this year was due to exhaustion of the soil by the production of large crops. This being the case, it would seem that irrigation has simply allowed the maximum crops to be produced each year which the rate of formation of soluble salts would allow, whereas

in the unirrigated land they accumulated during the dry season to be used during the season of greater rainfall.

There is, however, one respect in which the irrigation of these clay soils of humid regions may have a detrimental effect on the soil; that is, on the tilth. It seems to be becoming more difficult the last two or three years to get clover to start well either from the seed or after cutting. It has also seemed to the writer that the irrigated soil shows a tendency to run together and become more soggy than the unirrigated, and if this be true it may account for the difficulty with clover.

WORK AT STEVENS POINT.

Experiments on the very sandy soil at Stevens Point were begun last year, and a general description of the location and soil will be found in the Report of Irrigation Investigations for 1901[a] by Professor King.

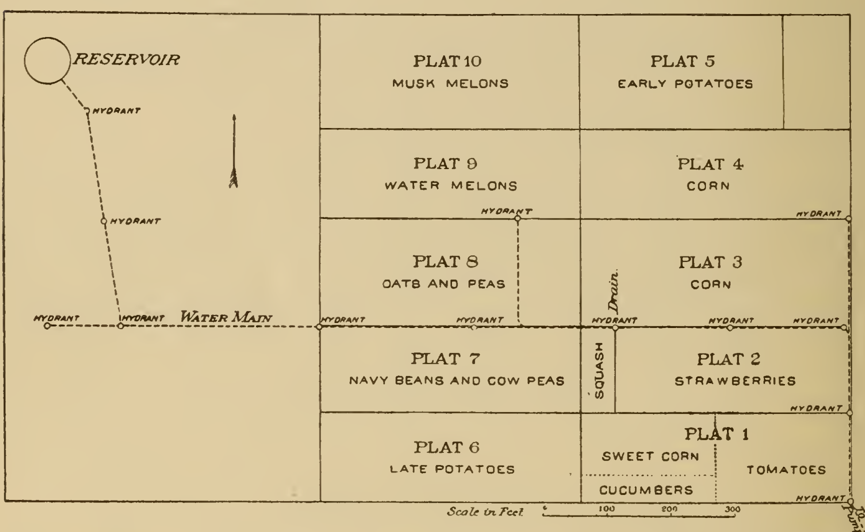


FIG. 14.—Plat of experiment field at Stevens Point, Wis.

THE IRRIGATION PLANT.

The pumping plant was used this year nearly as there described, but on account of the great difficulty with canvas hose for distributing mains the owner of the land put in mains of 10-inch sewer pipe.

The field, shown in fig. 14, is 30 acres in extent and is on a glacial river terrace having a general elevation of about 33 feet above the Plover River at this point. The differences in elevation on the field itself do not exceed 3 feet, but are sufficient to make it very difficult or impossible to get water to all parts by means of canvas hose,

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 119, p. 317.

hence a single line of main ending in a small reservoir on the highest part of the fields and having three branches was laid as shown in the diagram.

From this main the water is taken by means of risers placed at suitable distances apart and coming to the same level over the field, so that by means of canvas hose the water can be taken out at any point under a minimum pressure. The ends of the risers are closed by short lengths of canvas hose, around which twine is tied. The connection between these short pieces of hose and the distributing hose is made by placing hoops of one-fourth-inch steel wire at the ends of the two hose. By compressing one slightly it can be passed through the other. The general depth of the top of the main below the surface is 1½ to 2 feet, and there is a slight fall from all parts to a drain hole, as shown in the diagram. The pipe used is a special 10-inch pipe, made in 3-foot lengths, and having deep corrugated sockets to hold the cement.

There were required for the 30-acre field, as shown, 2,350 feet of pipe, including fifteen Y's, two T's, and fifteen one-eighth bends, and the price given is for pipe delivered at Stevens Point. The total cost for pipe and laying is as follows:

Cost of water main on field at Stevens Point.

Pipe	$385.08
Cement	27.00
Tools	2.07
Labor	95.85
Total	510.00

This makes a total cost of $17 per acre. This system, while expensive, is permanent and has given excellent results the present year.

PLAN FOR CROP EXPERIMENTS.

On account of the extreme sandiness of the soil and its lack of humus, the water-holding capacity is very small and the mineral matter of the soil becomes available only very slowly. Before these soils can be expected to yield good returns it will be necessary to increase the amount of humus very largely. This will increase the water-holding capacity and also the fertility, by bringing to the soil material which is readily made available to crops and by acting chemically on the soil to change it more rapidly into available forms. The experiments have therefore been arranged to include a study of the effect of manure as well as of irrigation.

Besides the difficulties due to the leachy and infertile character of the soil in its present condition, there are others with which the farmer or gardener has to contend. Chief among these are the sand storms, so

frequent in the spring and early summer. The sand, blown by the wind, cuts off corn, tomatoes, etc., as completely as a severe frost. Some study has therefore been given incidentally to methods of lessening the damage done in this way.

On account of the heavy rainfall, comparatively little increase was produced by irrigation, and, indeed, many crops were not irrigated at all. Since, however, the yields produced by rain can be taken as an indication of what they would be when water is supplied artificially, they will be given in detail.

RESULTS WITH THE SEVERAL CROPS.

CORN.

Corn was planted on plats 3 and 4 (see fig. 14, p. 226), which grew potatoes in 1901. Great difficulty was experienced with sand storms, which cut the corn so badly that it was necessary to replant parts of the plats two or three times, thus making them irregular. The corn did not mature, and was finally cut green to save it from frost, allowed to dry ten days, and weighed. In this condition it probably contained 30 to 40 per cent of water. The crop was not irrigated, but records were kept of the yields from subplats which received no manure, either last year or this, which were manured in 1901 but not in 1902, in 1902 but not in 1901, and both years.

Yield of partially dried corn and stalks per acre.

	Pounds.
No manure applied either year	5,721
Manure applied in 1901 only	6,852
Manure applied in 1902 only	7,636
Manure applied in 1901 and 1902	8,931

The land which was manured both years yielded a crop 56 per cent larger than unmanured land, while the single manuring this year caused an increase of 33 per cent. The single manuring produced a greater percentage of gain on this sand than it did on clay loam soil at Madison, which had received no manure for eight years. At the latter place the increase was but 23 per cent. While the above yield, even after two years of manuring, is still small, the increase is so large as to give hope that a few years more of such treatment would make it fairly productive with sufficient water.

The rainfall during the growth of this crop was 15.31 inches.

STRAWBERRIES.

The value of irrigation in fruit growing is greater than in vegetable raising, because in most cases the yield produced any year depends not only on the growth that year, but also on that of the year or years previous. In the irrigation, however, of such crops as strawberries,

which are grown in beds, and the roots of which are limited to a shallow depth of soil, the sandy land is at the greatest disadvantage.

The furrow system of distributing the water, which is the best and cheapest on ordinary soils and for such crops as corn and potatoes, gives fairly satisfactory results on sandy soils, fails utterly when applied to strawberries. This, at least, must be the conclusion from the experiments at Stevens Point. There are two ways in which damage is done in this case; too much water may be used, so as to cause excessive leaching, or washing of the side of the furrow may undermine the plants. If the water flows slowly, so as to avoid washing, it will be absorbed by a short length of furrow, and hence cause leaching. On the other hand, if the flow be great enough to give a reasonable amount of water there will be considerable washing. The latter difficulty is the one met with in the irrigation of the strawberries of 1901. Although the plants last year seemed to grow better where watered, the results this year show that the washing was very injurious. The yield on the irrigated ground was at the rate of 1,093 quarts per acre, while that on unirrigated ground was 1,638 quarts per acre. It seems to the writer impossible to irrigate strawberries on such soil unless some more satisfactory method of distributing the water be devised.

The rainfall during the growth of this crop was 13.33 inches.

TOMATOES.

Tomatoes were grown on a part of plat 1, as shown in the diagram (see fig. 14, p. 226). They were set out in hills June 4 and 5 and were protected from the sand by shingles. Light dressings of sodium nitrate were given three times, amounting in all to 75 pounds per acre. The irrigated portion of the plat was watered twice, with a total of 2.53 inches. The cost was—for fuel, 72 cents; for preparing the ground, 25 cents, and for distributing, 16 cents, or a total of $1.13 per acre.

The yield on irrigated ground was 5,637 pounds per acre, and on unirrigated ground 5,278 pounds per acre. The average selling price was 2 cents per pound, making the income $112.74 and $105.56 per acre, respectively, or a difference of $7.18, which leaves a net profit of $6.05 due to irrigation. The plants were set out two weeks too late, and on account of the cold weather a large part of the summer a considerable part of the tomatoes did not ripen and the price received for those which did was small. With irrigation this crop ought to be a thorough success on this soil. The water received by this plat during growth, including rainfall, was 10.64 inches.

POTATOES.

Early Ohio potatoes were grown on plat 5, part of which had received coarse manure at the rate of 20 loads to the acre. Part of

the field was irrigated August 8 with 1.03 inches of water. The yield of saleable potatoes was as follows:

Yield of early potatoes per acre.

	Irrigated.	Not irrigated.
	Bushels.	*Bushels.*
Manured	93.4	81.3
Unmanured	62.9	58.0

The cost for irrigation was: For fuel, 34 cents; for preparing the ground, 25 cents; for applying water, 15 cents; making a total of 74 cents per acre.

Late potatoes were planted on plat 6, part of which was also manured. Water was applied August 12 and 27, the total amount being 5.19 inches. The yield of saleable potatoes is given in the following table:

Yield of late potatoes per acre.

	Irrigated.	Not irrigated.
	Bushels.	*Bushels.*
Manured	115.1	102.0
Unmanured	75.9	69.6

The cost of the irrigation per acre was as follows:

Fuel	$1.53
Preparation of land	.25
Application of water	.67
Total	2.45

The potatoes were sold this year at 20 cents a bushel. At this price the increase by irrigation on manured land just covered the cost of irrigation, while on the unmanured land there was a deficit. The rainfall during the growth of crop was 12.18 inches.

WATERMELONS.

Watermelons were planted on plat 9, part of which had been manured at the rate of 20 loads to the acre. The area of the plat is 1.377 acres. Owing to the lateness of planting and injury by sand storms these melons did not ripen, although they had reached full size.

The number of melons on the manured land was 1,415, and on the unmanured land 1,107 per acre.

The entire plat was irrigated August 27 with 0.725 inch, which, in addition to the rainfall during the period of their growth, made a total of 12.645 inches of water. Melons of this size were selling on the local market at 8 to 10 cents apiece at the end of the season.

MUSKMELONS.

Muskmelons were grown on a piece of ground near the reservoir having an area of 0.178 acre. The yield on this piece was at the rate of 1,820 melons per acre. They were not irrigated, and the rainfall during their growth was 13.39 inches.

CUCUMBERS.

A portion of plat 1 was planted with cucumbers, part being manured and part unmanured. The entire plat was irrigated with 1.77 inches of water August 20, and the yield follows:

Yield of cucumbers per acre.

	Manured.	Unmanured.
	Bushels.	*Bushels.*
Large	57.7	20.8
Small	95.8	86.0

The rainfall during the growing period was 8.21 inches, and this together with the 1.77 inches made the total amount of water 9.98 inches.

The small cucumbers were sold at $1.25 a bushel and the large ones at 50 cents a bushel. The gross returns on the manured land were therefore $148 per acre.

SQUASH.

A piece of ground amounting to slightly more than one-tenth of an acre was planted to Hubbard squash. The yield was at the rate of 710 of large size per acre and they were sold at 12 cents apiece. There was no irrigation, and the rainfall during their growth was 7.92 inches.

COST OF IRRIGATION.

The average of all determinations made this summer shows that the pumping of an acre-inch of water to a height of 35 feet—the level of discharge—required 2.714 gallons of gasoline, which at 12.5 cents a gallon makes the cost for fuel 33.9 cents per acre-inch. The average cost of fitting the ground has been 24 cents per acre and for distributing the water 14 cents per acre-inch, counting wages at $1.50 per day for a laborer and $2.25 per day for a man and one horse. The average rate of pumping has been 540 gallons per minute, or 1.2 cubic feet per second.

RAINFALL AND EVAPORATION.

As previously stated, the rainfall this year has been somewhat larger than the average, amounting during the six months, April to Septem-

ber, inclusive, to 22.33 inches at Stevens Point, as recorded by Prof. G. E. Culver. Its distribution is given in the following table:

Rainfall at Stevens Point, Wis., from April 1 to September 30, 1902.

Date.	Rainfall.	Date.	Rainfall.	Date.	Rainfall.
	Inches.		*Inches.*		*Inches.*
April 6	0.30	May 24	0.84	July 31	0.81
April 22	.27	June 2	.81	Aug. 8	.10
April 25	.17	June 7	.58	Aug. 12	.35
April 26	.85	June 12	.16	Aug. 14	.10
May 2	.38	June 20	.66	Aug. 30	.27
May 4	1.49	June 21	.03	Aug. 31	1.00
May 6	.70	June 25	.92	Sept. 5	.50
May 8	.80	July 2	.86	Sept. 6	1.21
May 10	.50	July 13	.20	Sept. 8	.35
May 12	.78	July 14	.36	Sept. 17	.09
May 18	1.22	July 19	.10	Sept. 23	.15
May 19	.70	July 20	.37	Sept. 27	.69
May 21	1.06	July 22	.05		
May 23	.41	July 25	1.29		

The evaporation was taken daily from June 2 to September 30 by means of a large evaporimeter. The evaporation was, in June, 6.14 inches; July, 5.62 inches; August, 4.41 inches, and in September, 3.50 inches, making a total for the four months of 19.67 inches. The daily evaporation is given in the following table:

Daily evaporation at Stevens Point.

Day.	June.	July.	August.	September.	Day.	June.	July.	August.	September.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	....	0.23	0.18	0.19	18	0.29	0.15	0.14	0.20
2	0.02	.03	.19	.13	19	.32	.11	.11	.13
3	.30	.10	.15	.20	20	.10	.12	.11	.05
4	.29	.19	.14	.10	21	.17	.15	.17	.00
5	.22	.17	.22	.04	22	.20	.09	.18	.03
6	.15	.21	.23	.14	23	.22	.10	.17	.17
7	.13	.35	.22	.13	24	.21	.11	.13	.19
8	.21	.20	.15	.12	25	.24	.13	.13	.05
9	.30	.27	.11	.12	26	.22	.19	.14	.02
10	.13	.26	.23	.15	27	.15	.21	.15	.00
11	.34	.30	.23	.19	28	.30	.20	.16	.06
12	.03	.26	.11	.11	29	.24	.20	.09	.03
13	.18	.22	.02	.14	30	.26	.18	.02	.19
14	.02	.20	.05	.16	31	....	.14	.14	....
15	.24	.30	.12	.16					
16	.31	.16	.12	.20	Total	6.14	5.62	4.41	3.50
17	.35	.39	.10	.10					

TREATMENT OF VERY SANDY SOIL.

INCREASING HUMUS.

As previously mentioned, the infertility of this soil and low water capacity are due to the lack of sufficient humus. The first effort in reclaiming this soil should be to increase the humus content. This is difficult at first, because the looseness of the soil allows the air to penetrate the soil so easily that the humus is rapidly oxidized. But as humus accumulates it holds water and lessens the change of air, so

that it becomes easier to keep the humus the more there is in the soil. So, while improvement is difficult and slow at first, it becomes easier and more rapid if persistent efforts are made. And on such ground as this which is to be used for market gardening the importance of irrigation in allowing catch crops to be grown for this purpose can not be overestimated. To estimate the effect of the application of manure the previous year on the water-holding capacity of the soil a number of determinations of the moisture in the soil were made on plats manured and unmanured in 1901. The average percentage of water in the first 3 feet of manured and unmanured land, as shown by nine determinations made on May 19, 20, and 22, 1902, is given in the following table:

Percentage of water in land manured and unmanured in 1901.

Depth.	Manured.	Unmanured.
	Per cent.	*Per cent.*
First foot	11.13	10.73
Second foot	7.30	7.18
Third foot	5.25	5.27

A second series of five determinations was made on June 19 and 20, 1902, after the weather had become drier, with results as follows:

Percentage of water in soil manured and unmanured in 1901.

Depth.	Manured.	Unmanured.
	Per cent.	*Per cent.*
First foot	9.94	8.71
Second foot	6.25	5.91
Third foot	4.12	4.22

In all cases the percentage of water in the first and second feet is greater on the manured than on the unmanured land, but that in the third is less. These differences are, of course, not large, but they may have an appreciable effect on the crop. The first set of determinations indicates that the first foot contained 16,000 pounds more water in the manured land, and the second set shows 49,200 pounds difference per acre. It will, of course, take several years to increase the water capacity of these soils very largely.

SAND STORMS.

The destructive effect of sand storms on this land is often so great as to ruin entirely such crops as corn, tomatoes, and melons. To prevent this damage the fields should be surrounded by protecting growths of wood, and they should be cultivated in narrow lands running north and south. Rye sown in the fall or oats and peas sown in

the spring, in narrow lands, alternating with the crop they are to protect or even in alternating rows with tomatoes, and cut off after danger from the spring storms is past, will greatly lessen the damage.

ACKNOWLEDGMENTS.

Acknowledgment is hereby made of the assistance rendered by Mr. W. B. Richards, who had charge of the details of field work and experiments, and by Prof. G. E. Culver, who kindly furnished us with meteorological data.

IRRIGATION INVESTIGATIONS IN NEW JERSEY, 1902.

By E. B. Voorhees,
Director New Jersey Agricultural Experiment Stations.

The investigations that have been carried on in this State have shown, first, that, while in many years the average rainfall is more than sufficient to meet the demands of vegetation, there occur periods during the year when one or more crops suffer from the lack of water, and hence that an irrigation plant in the trucking and fruit-growing districts would be of service every year for one or more crops. In the second place, it has been shown that irrigation on a small scale is entirely practicable and profitable—that is, that plants costing from $150 to $600, and capable of irrigating from 1 to 10 acres, are desirable adjuncts to farming. Thus one of the main problems connected with irrigation in the humid districts is practically settled, namely, that water may be got to plants and at a profit. The problem which still remains to be studied is whether it is practicable, particularly in those districts where the soils are poor, but well adapted to sweet potatoes, small fruits, and other vegetable crops, to carry the water in open ditches. It has been shown that there is sufficient water, and also that it can be carried over the land, but whether it is practicable to take water from streams and carry it through ditches in that open, porous soil such distances as may be necessary in order to utilize it for purposes of irrigation has not been tested.

CARRYING WATER IN OPEN DITCHES.

There are many places in the State where ditches have been used for carrying water to water wheels, but in these cases either the land lies reasonably low or it is of a different character than that in the districts where irrigation would be found to be most serviceable. Hence a part of the investigations reported herewith have been along these lines, and, fortunately, it has been possible to obtain the right to carry a ditch through private property for the purpose of studying this point. This plant is located at Cedar Lake, N. J., where a canal half a mile long, dug some twenty years ago, but not now used, could be utilized in part for this work, thus reducing very materially the cost of the experiment. The original cost of the canal already dug was $1,000,

and it was made to carry water out of the main bed of a stream around the edge of a cranberry bog, and at the same fall as the natural stream. By building a dam across this canal, so as to raise the water 4 or 5 feet, it was possible to carry the water in a new canal on new ground for another half mile or more. The purpose was to study, first, the cost of construction, and, second, the losses of water from the canal. It was expected that the expense in renewing the old canal would be very slight and that after it was fitted up the loss of water would be small. It was found, however, that on account of washouts, muskrat holes, etc., along the banks of the old canal, the expense was much greater than had been expected and that the loss of water from seepage was greater than in the case of the newly made ditch.

Fig. 15 shows the various parts of the canal and the ditch. The original canal begins at 1. There was formerly a dam across the main stream at this point, so that all the water in the stream could be

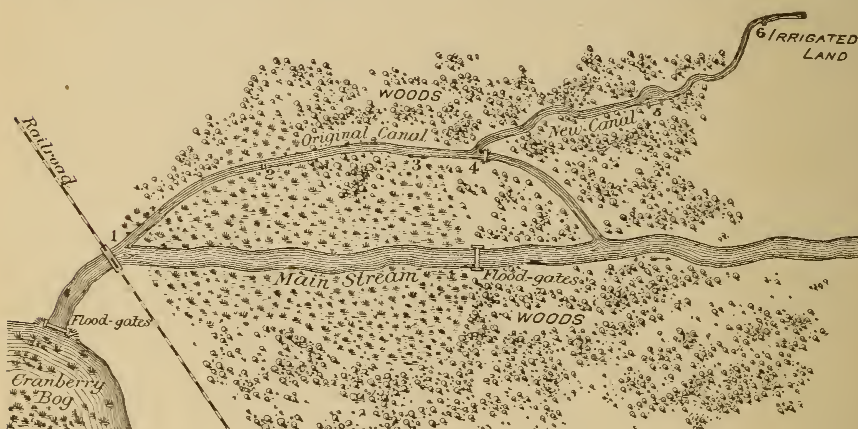

FIG. 15.—Map of canal at Cedar Lake, N. J.

diverted into the canal when desired. At 2 there is a sewer 1 foot in diameter, leading under the canal to let the water out of the swamp, shown in the drawing. At 3 is a flood gate, for letting out the water in the canal in cases of heavy storms or sudden showers causing a rise of water that would be likely to endanger the dam or the sides of the canal. At 4 is a dam thrown across the canal for diverting the water into the new ditch for carrying the water to 6, where it was to be turned upon the land to be irrigated. This ditch is about 2,200 feet in length, and is carried on high ground through the woods. The ground was broken with a plow and the dirt thrown out with shovels. A large part of the ditch is along the slope of a hill, where a vein of coarse sand 1 foot in thickness was dug through.

On July 25 the amount of water flowing into the head of the canal was 3.25 cubic feet per second. The amount of water flowing into the

FIG. 1.—WATER FLOWING IN DITCH LINED WITH TARRED CLOTH.

FIG. 2.—DITCH LINED WITH CLOTH, EMPTY.

newly made ditch at 4 was 0.8 cubic foot per second. Thus there was lost 2.45 cubic feet per second from the main canal in a distance of a quarter of a mile. The water flowed into the ditch for seven hours without going farther than 600 feet, and it could be seen seeping out all along the base of the hill on the side of which the ditch was dug.

EXPERIMENT TO PREVENT SEEPAGE.

Clay was hauled from a distance and thrown into the ditch and thoroughly puddled for several days, so that a coating of clay could be seen all along the bottom and sides of the ditch. Seven 1-horse loads of clay were used in a little less than half a mile of ditch, and during the fall water flowed the entire length of the ditch with apparently little loss. The amount of water flowing was not measured at different points, however, until November 23. Before this date the ditch had been allowed to run dry for a distance of about 400 feet and the bottom had frozen. The sides of the ditch for some distance between 5 and 6, together with some of the bottom of the pond at 4, had also frozen, and, although the clay was thoroughly stirred again, it was apparent that there was not so large a proportion of water coming out at 7. The measurements given below were taken November 23.

	Cubic feet per second.
At 1	1.25
At 4	.83
Between 4 and 5	.81
Before 5	.75
Half way between 5 and 6	.47
At 6	.27

The loss of water in the old canal is seen to be much smaller in proportion to amount flowing in than on July 25, and the greater part of this loss is from the constant leakage under the dam and at the water gate. The loss from 4 to 5, a distance of 1,250 feet, is comparatively small considering that before using clay all the water soaked away in the first 600 feet of this section of the ditch. The lengths of sections of the ditch are: The old canal, from 1 to 4, 2,600 feet; the new ditch, from 4 to 5, 1,250 feet, and from 5 to 6, 920 feet. From 6 to the end of the ditch is several rods, and it could be extended about half a mile if land that is now in woods were to be irrigated.

December 12 the flow was again measured. Before this nearly the entire new ditch had been dry and the bottom had frozen. At 4 the flow was 1.2 cubic feet per second; before 5 it was 0.75 cubic foot per second. The loss here of nearly 40 per cent, as compared with a loss of 10 per cent November 23, shows the necessity of either keeping the bottom of irrigation canals from freezing or else of puddling them afresh every spring.

During the winter the dam at 4 was washed away. This was very carefully rebuilt at a cost for labor and material of about $35. It was impossible, however, to make a success of it, on account of one or more springs under the dam which gradually washed it away. It was therefore abandoned and another dam thrown across the old canal 50 yards farther up and the ditch extended to that point. This new dam and ditch extension cost about $6 for labor.

Water was started down the ditch May 14 and had run down 1,600 feet by the next morning. There was considerable leakage at the counterdam, shown in Pl. XII, fig. 1, and in fig. 15, at No. 5, also under the ditch just before 5. At this point the ditch runs along the hillside. After running into the ditch continuously the water started out of the end in a small stream May 20. May 26 water was still running continuously and the seepage had stopped under the ditch just above 5. This shows clearly that seepage losses tend to disappear as a ditch is used longer. The seepage while passing over the raised ditch was also considerably less May 26.

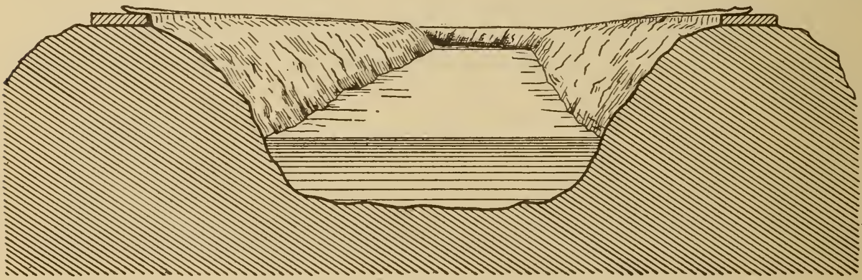

FIG. 16.—Ditch lined with tarred cloth.

Measurements of water at the head of the ditch and at the outlet May 28 showed a flow at the head of 1.3 cubic feet per second and at the outlet a flow of 0.8 cubic foot per second, a loss of 38 per cent in a little less than one-half mile.

At the outlet, as shown in Pl. XII, fig. 2, the water runs in a ditch dug in the top of an embankment. The water seeped so badly that it was impracticable to run it through the ditch until tarred cloth had been laid in the bottom (fig. 16). After this was done there was no seepage. Tarred cloth is to be used at 5 also. The water has twice washed over or through the sides at this point and necessitated considerable expense for repairs. These limited experiments with tarred cloth demonstrate that by covering the bottom and sides of the ditch in this way practically all of the water could be carried a long distance in any ditch. That is, it prevents seepage to a considerable extent.

In July a systematic test of two other methods of overcoming seepage was inaugurated. The first was to allow the water to run in the

ditch at about the same depth for a long time. The second, to haul clay and throw it in the bottom of the ditch and afterwards to stir it up thoroughly while the water was running, so as to secure a thin film of sediment over all the bottom and sides of the ditch. July 24 3,000 pounds of clay were thrown into the ditch in shovelfuls, but were not stirred at that or at any other time during the summer, so the effect on seepage was probably very little. July 25 the water had been running in the ditch for several days. Measurements were made at the beginning and end of the new ditch by means of weirs. The weir consisted simply of a board long enough to extend across the ditch and into the bank on either side, with a notch 1 foot long sawed out of the middle. The boards were inserted in the ditch in such a way as not to raise the water above more than an inch, and then measurements were taken at intervals to be sure that the flow had become regular. July 25 at the weir near the head of the ditch the water flowed over it 3 inches deep. At the weir near the end of the ditch the water was 2.5 inches deep. July 29, at 9 a. m., the water near the head of the ditch measured $1\frac{1}{16}$ inches deep. Another board was then put on the dam and the water rose at outlet until 11.15 a. m. At 11.45 the depth at head of the ditch was $4\frac{1}{4}$ inches; near outlet of ditch, $3\frac{1}{2}$ inches. These measurements show that as the water rises it soaks away much more rapidly. Although it does not spread out much along the ditch, it evidently soaks away along the upper edges of the banks. Further measurements were made as follows: August 2, near dam, $3\frac{1}{4}$ inches deep; near outlet, $2\frac{5}{8}$ inches deep: August 9, near dam, $2\frac{3}{8}$ inches deep; near outlet, $2\frac{2}{8}$ inches deep; August 16, near dam, $1\frac{1}{16}$ inches deep; near outlet, $1\frac{1}{16}$. It should be borne in mind that the opportunity for seepage from this ditch was probably as great as it would be in any ditch in southern New Jersey. The slope is only 2 feet per mile; the ditch runs along a side hill for a considerable distance, and the bottom of it is dug through a vein of glass sand, which allows the greatest possible opportunity for the water to seep, since this vein slopes the same as the hill.

Just how much could have been attained by a persistent attempt to run water in the ditch without puddling with clay is not known, although, as previously reported, an attempt to determine this was made a year ago, when the ditch was dug. The water ran down the ditch a few hundred feet and stopped, all of it seeping away for several days. Several thousand pounds of clay were then thrown into the ditch and puddled thoroughly. This clay probably helped in making the ditch hold water. Nevertheless, this year in the spring it seeped very badly.

TARRED CLOTH AS DITCH LINING.

The further trial of tarred cloth as lining for a ditch, made along the middle of a dike to carry water across a ravine, shows that a ditch

of this character will hold water quite well as soon as the sand has become settled. When 12-ounce duck cloth is used there is practically no seepage, even where the sides are built of turf and sods, under which conditions, without the tarred cloth, the water would seep out as through a sieve. A trial was made of tarring light muslin, but the one heavy coat of tar did not make it water-tight.

DANGER FROM WASHOUTS.

If the dam and those parts of the ditch most difficult to repair are made high and an opportunity is given at some other place or places for the water to overflow the banks in case of sudden storms, the expense of constant watching need not be incurred. If some one living near the dam can be trusted to open the gates at the beginning of every storm and to have a general oversight of the canal, the danger from washouts is largely eliminated. If water is stored in large ponds, it will be necessary to have some one live near, as in the case of cranberry bogs, to see that no damage is done by floods.

CROPS PLANTED.

A plat containing 1½ acres of ground, as poor as can be found in south Jersey, was planted with sweet potatoes and cowpeas. The fertilizer used on the sweet potatoes and on part of the cowpeas consisted of 1,200 pounds of tobacco stems and 400 pounds of South Carolina rock per acre. The remainder of the cowpeas were fertilized at the rate of 200 pounds of muriate of potash and 600 pounds of South Carolina rock per acre. The 3,000 sweet-potato plants were badly injured by the heavy frost of May 29 and yielded only a meager crop of potatoes. As is well known, the sweet potatoes grown on this very sandy land sell for the highest prices. Enough navy beans were planted where the sweet potatoes died to learn what they would do, and a fair crop was harvested.

Some of the cowpeas were sowed in rows and some broadcast. A moderate growth was secured. One-half of the broadcasted were plowed under October 26, and rye sowed. Rye was sowed among the cultivated cowpeas and cultivated in, the intention being to plow under rye and peas together in the spring. The half of the broadcasted not plowed under will be plowed under next spring. The object of plowing under green crops is not only to improve the land, but to see if it will not be easier eventually to irrigate in open ditches because of the lessened porosity of the soil.

DISTRIBUTION OF WATER ON THE LAND.

As already pointed out, during the fall, after the ditch had been thoroughly puddled, there seemed to be about as much water coming out at 6 as entered at 4. When the distribution of the water was tried

during the warm weather in December, only a small proportion of what left the ditch could be carried to the land. The attempt to distribute the water by means of ditches was made, but so much water was lost by seepage that this method was abandoned, since it would not be practicable to have all ditches puddled with clay.

Distribution through tarred-cloth hose was then tried. This hose is made according to directions given in Bulletin 87 of the Office of Experiment Stations, United States Department of Agriculture. Pieces of this hose can be readily fastened together by inserting a short piece of iron pipe or of stovepipe into the end of each length and tying the hose on with a string. Hose 7 inches in diameter, 350 feet in length, was laid on the bottom of the ditch, where the slope was not more than 2 feet to the mile. When water was allowed to flow into this hose, under a head of 6 inches, it came out at the end at the rate of 30 gallons per minute. When the slope is 4 feet in about 500 the flow will be from 100 to 150 gallons per minute, thus making it entirely practicable to to use this method for distributing the water from ditches over a large area of land in south Jersey, as a large portion of it has a slight slope.

Furrows were run about 3 feet apart across the plat of very sandy soil, and during a warm spell in December water was run into these furrows from tarred hose, as above described, at the rate of 30 gallons per minute. The land was watered at the rate of an average depth of 1.5 inches over the entire surface. If, therefore, the entire amount of water of the stream July 25—4.91 cubic feet per second—was carried in a ditch a distance of 1 mile and used there for irrigation at the rate of 1.5 inches, more than 778 acres could be irrigated every ten days. If the ditch were puddled with clay and 50 per cent of the water were lost in the ditch, 311 acres could be irrigated. Later than July 25 there was only about one-half as much water in the stream as on that date.

This very sandy soil allows the water to pass through with such perfect ease that irrigation in open ditches was hardly practicable on the plat described. This is true although the slope of the land is greater than is usual on this very sandy land of south Jersey.

In the case of the sweet potatoes, one-third acre was irrigated June 7 and again June 11, by flowing the water between the rows. The first time five hours were required, the second time three and one-fourth hours, both times using all the water that came down the ditch. A large proportion of the water seeped away while running across the middle of the field in a temporary main ditch. While the method previously described of using tarred-cloth hose to carry water to various parts of the field could be used here with greater economy of water, the water seeps away so rapidly that it would be quite laborious to change the hose as often as would be necessary. It is hoped that this difficulty in distribution of water can be overcome

by working the soil and incorporating humus in it. Thirty years ago the soil along Landis avenue, Vineland, had the appearance of being incapable of growing grass—it appeared to be mere drifting sand. Now the soil is quite heavy and the roadside is covered with a tough sod.

It is quite possible that the best way to irrigate sandy land will be to carry water in canals as near to the field to be irrigated as possible and then pump the water to sprinkle it over the ground. At present the great problem of irrigating sandy soils is that of economical distribution of water.

EXPERIMENTS AT VINELAND.

Sweet potatoes, peaches, and alfalfa were to have been irrigated, but it was not necessary on account of the rainy season.

SWEET POTATOES, EXPERIMENT NO. 1.

This experiment was for the purpose of determining whether it is better to irrigate often with a small quantity of water or to thoroughly soak the ground at longer intervals. The variety was the Jersey Big Stem. July 3 to 5, both plats were irrigated. On plat 1 the water was run in every space between the rows, about 2 inches being applied. On plat 2 the water was run in alternate spaces, about 1 inch being applied. The plats consisted of 0.216 acre each. Plat 1 yielded 15.2 barrels of primes and 6 barrels of seconds. Plat 2 yielded 10.7 barrels of primes and 5⅓ barrels of seconds. Reduced to an acreage basis the yields were: Plat 1, 70.4 barrels of primes and 27.8 barrels of seconds; plat 2, 49.5 barrels of primes and 24.7 barrels of seconds. The gain from the larger quantity of water applied between the rows is very marked.

SWEET POTATOES, EXPERIMENT NO. 2.

The plan of this experiment was to irrigate one plat thoroughly soon after setting, and again the latter part of August or 1st of September. Another plat was to be irrigated once only, at the same time as the second irrigation of the first plat. A third plat was to be unirrigated. Since no irrigation was needed after July 7, the second plat was left out. The plats were 0.2 acre each. The fertilizer used was 1,100 pounds tobacco stems and 550 pounds South Carolina rock per acre. The plants (Yellow Nansemond) were put out with a tobacco transplanter May 17. A hand weeder was dragged over the ridges May 17, 28, and 30. This weeder worked on the same principle as the regular horse weeders. The sweet potatoes were cultivated June 4, 13, 17, July 10, 17, 22, and August 1. They were irrigated with 2 inches of water July 1, and harvested October 7. The irrigated plat yielded 8.75 barrels of primes, 0.66 barrel of very large, 2.25 barrels of sec-

onds, and 1.5 barrels of small potatoes. The unirrigated plat yielded 8.2 barrels of primes, 0.6 barrel of very large, 2.56 barrels of seconds, and 1.5 barrels of small potatoes. The yield from the irrigated plat is not noticeably larger than that from the unirrigated plat.

PEACHES, 1901.

The trees experimented on were set out in the spring of 1897, and are of the Late Crawford variety. Thirty-two trees were irrigated during the summers of 1900 and 1901. Fourteen other trees were irrigated very little in 1900, and not at all in 1901. The 32 trees were irrigated June 30. Most of the water was applied right around the trees to an amount equivalent to 1 to 1.5 inches over the whole surface. The orchard was plowed once, cultivated seven times, and harrowed for last working August 23. The peaches were thinned the 1st of July; quite a good many peaches rotted. The yield of prime peaches from the irrigated plat was, September 9, 267 pounds; September 10, 11, 12, and 13, 588 pounds, a total of 855 pounds, and an average per tree of 26.7 pounds. The unirrigated plat yielded, September 10 and 11, 252 pounds, an average of 18 pounds per tree. The gain from irrigation was 8.7 pounds per tree, or 1,392 pounds per acre. At 50 cents per basket of 25 pounds, the gain per acre is $27.84. It is evident that irrigation caused later ripening, which is an advantage with this variety.

PEACHES, 1902.

This is a continuation of last year's experiment. One tree from the unirrigated and two from the irrigated plats have died from the effects of the San José scale, making 13 trees on the unirrigated and 30 on the irrigated from which fruit was gathered this year. Fertilizing was at the rate of 4 tons of stable manure, 550 pounds of tobacco stems, and 60 pounds of nitrate of soda to the acre. The orchard was plowed once, cultivated four times, and harrowed four times during the summer. The dates of picking and the yields were as follows:

Thirty irrigated trees—August 29, 3¼ baskets; September 1, 12 baskets; September 3, 13⅝ baskets; September 5, 15¼ baskets; total, slightly over 44 baskets. Thirteen unirrigated trees—August 29, 2 baskets; September 1, 12 baskets; September 3, 8 baskets; September 5, 6 baskets; total, 22 baskets. The yield per tree was, irrigated, 37 pounds; unirrigated, 42.3 pounds, a difference of 5.3 pounds per tree in favor of the unirrigated trees. In 1901 the difference was 8.7 pounds per tree in favor of the irrigated trees.

ALFALFA, 1901.

A small plat of 3 square rods was sowed to alfalfa, as a test of the practicability of growing this plant in this section. Seed from Utah

was used, and some soil from the alfalfa field on the experiment station farm at New Brunswick was scattered over the plat to introduce the alfalfa bacteria. June 17, 3 bushels of lime were raked into the soil, the seed was sowed and raked in, and the ground was rolled. A mulch of hay was put on and was taken off two days after the seed started to come up. The plants were damaged by the mulch being on too long.

June 29 and July 2 the plat was irrigated by flooding. A large number of new plants came up after the first irrigation, showing the advantages of irrigation in alfalfa growing. After the last irrigation 100 pounds of tobacco stems were scattered over the plat. The alfalfa was mowed July 30 and August 23, and in the fall had made a good growth.

ALFALFA, 1902.

The plat of 3 square rods that was sowed to alfalfa June 17, 1901, was mowed three times in 1902, yielding, May 24, 42 pounds of hay, July, 32 pounds, and August 7 (calculated), 30 pounds. Before August 7 the soil from one-fourth rod was removed to scatter on a field of young alfalfa. This year's yield is equal to 2¾ tons per acre. At the end of this second season of its growth the plat has become quite grassy and weedy, and goes into winter in much poorer shape than after the first season.

In the spring of 1902 an acre of good ground was limed and cultivated several times. April 27, 27 pounds of seed were sowed in two sowings, in order that some could be planted deeply and some very shallow. It came up well, but soon began to look very yellow. On June 30 several wagonloads of soil were taken from the plat of alfalfa where root tubercles were quite plentiful and this soil was scattered over the acre. Frequent showers washed this soil in, but it did not appear to have any immediate effect. Manure was put on, some of it in July, without much effect. Nitrate of soda appeared to keep the alfalfa alive, and on August 1 75 pounds were broadcasted. At the end of the season there are large spots where the alfalfa appears to have completely died out. The field will be left to grow another season, as the results so far obtained are not conclusive. No irrigation was required this year.

WATER SUPPLY OF NEW JERSEY.

During the early part of September, 1900, after the driest summer known in south Jersey in many years, the discharge of several streams was measured with a view to determining the quantity of water available for irrigation.

Manantico Creek was measured September 14, 1900, and was found to be discharging 16.5 cubic feet per second. At the rate of 3 acre-inches every ten days about 980 acres of land could be irrigated if

not more than one-fourth of this water were lost by seepage in the canal.

Tuckahoe River was measured September 11, 1900, at Hunters Hill, and showed a discharge of 24 cubic feet per second.

Parvins Branch was measured September 19, 1900, at Malaga Road, and showed a discharge of 2⅜ cubic feet per second.

SUPPLY OF WATER FROM WELLS.

Owing to the difficulties and expense that are involved in carrying water from streams through canals, and to the fact that the use of water from streams interferes with water rights, the supply from wells is a matter of importance. The wells described have been recently sunk, and a study of the supplies shows the possibilities of irrigation from wells, many of which show a supply equal to those in use in southern California.

The annual reports of the New Jersey State geologist, since 1889 particularly, contain accounts of a large number of artesian wells throughout the State. These reports contain very complete maps of the strata underlying southern New Jersey. By means of these maps quite accurate estimates as to the depth at which water can be secured in a given locality can be made. A number of water horizons exist in southern New Jersey, from which water can be drawn through wells. Even where the depth of the different water horizons can not be accurately foretold, a great deal of information may be secured by examining other borings. Driven wells and bored wells are becoming so common now that wells can be found near enough to almost any locality where it is desired to put down a well to afford some idea of what is to be expected in the way of expense and water supply. It would be far safer, however, to consult an expert on the geology of New Jersey if any great expense is contemplated.

As examples of what flow of water can be obtained from wells in some parts of southern New Jersey the following may be taken:

VINELAND.

The wells driven by Charles Keighley & Sons to secure a water supply for the borough of Vineland and the wells driven at the New Jersey Training School for Feeble-minded Children are fully described in Bulletin No. 36, Office of Experiment Stations, United States Department of Agriculture. These wells show a plentiful and constant supply of water at a depth of between 100 and 150 feet. In 1901 six new 6-inch wells were put down for a city water supply. These wells are from 125 to 150 feet in depth, and one well has yielded 250 gallons per minute, showing no sign that this was the maximum. The usual daily output is 1,000,000 gallons.

MILLVILLE.

The Millville Water Company, which before 1901 drew its water supply from the large mill pond, has sunk three wells, with a view of using well water to supply the city. One well, 700 feet deep, was not a success, because solid rock was encountered that might be very thick. The most copious supply was found at a depth of 200 feet. This well was 4.5 inches in diameter, and yielded 150 gallons per minute. The other two wells were 84 and 90 feet deep, respectively. Either one will yield 100 gallons per minute. These wells are 42 feet apart, and when water was pumped from one well it reduced the flow of the other 50 per cent. The wells flow at from 7 to 9 feet above tide water. The People's Water Company of Millville has put down six 8-inch wells, averaging 102 feet in depth. These wells are driven close to the river, and they flow all the time, but they have not been tested to learn their maximum discharge.

CLAYTON.

The towns of Clayton and Glassboro are supplied with water from four 6-inch wells at Clayton, averaging about 100 feet deep. January 4, 1902, 12,600 gallons per hour was being pumped from these wells. Fifteen thousand gallons per hour has been pumped with no sign that this was the limit of their capacity.

Moore Brothers drove five 3-inch and four 2-inch wells near the four just described. They have pumped 300 gallons per minute from them. Since driving the wells two of them have closed, but the other wells are now considered safe for a delivery of 150 gallons per minute. One 3-inch well 95 feet deep will yield 100 gallons per minute, but no other of the 3-inch wells will do as well. The water comes from a stratum of very coarse gravel which underlies marl at a depth of 95 to 105 feet. The wells are 25 feet apart. The water rises to within 30 feet of the surface. These wells were put down with ordinary points, with opened end, at an estimated cost of $900 for the group.

GLASSBORO.

Five wells 70 to 80 feet deep, belonging to the West Jersey Railroad Company, furnish 100 gallons per minute.

The New Jersey Packing Company put a well down 526 feet without securing a large quantity of water at any place. Some of the workmen thought a good supply of water was found at 250 feet and that the contractor drove through it and shut it off. The expense was between $800 and $900.

PITMAN GROVE.

There are several wells here 140 to 200 feet deep that yield 12 to 15 gallons per minute; they have not as a rule, however, been tested

for maximum flow. One well at the city waterworks, 507 feet deep with water 150 feet from the surface, yields 50 to 60 gallons per minute. It was intended to sink the well deeper, but very coarse gravel prevented. The water is blown out by means of compressed air.

SEWELL.

F. J. Anspach, of Sewell, owns a well 420 feet deep in which the water rises to within 77 feet of the surface. Continuous pumping of 40 gallons per minute has not lowered the water.

SWEDESBORO.

A 6-inch well 130 feet deep has recently been put down at Swedesboro. The well flows 90 gallons per minute with no sign of giving out.

WOODSTOWN.

Six 6-inch wells supply Woodstown with water. These wells are on low ground and flow at the surface, as does the Swedesboro well. During tomato-canning season 150,000 gallons of water are needed daily, but the flow from the wells is hardly sufficient to meet this demand.

MULLICA HILL.

An 8-inch well 265 feet deep yields 100 gallons per minute and shows no sign of exhaustion. Probably 200 gallons per minute could be pumped.

SALEM.

J. Q. Davis sunk three 4.5-inch wells at Salem, which together yield 300 gallons per minute. A well 248 feet deep, which yields 55 gallons per minute, was put down at Quinton for the Salem Water Company.

EVAPORATION.

Record of evaporation at New Brunswick, July, 1901, to July, 1902.

Dates of reading.	Gain or loss in tank.	Rainfall.	Evaporation.	Dates of reading.	Gain or loss in tank.	Rainfall.	Evaporation.
1901.	*Inches.*	*Inches.*	*Inches.*	1902.	*Inches.*	*Inches.*	*Inches.*
July 20	+4.090	5.62	1.530	March 15	Filled.	....	....
August 3	− .700	1.90	2.600	March 29	None.	1.35	1.350
August 17	+2.120	3.47	1.350	April 12	0.875	2.16	1.285
August 31	+2.875	5.43	2.555	April 26	−2.200	....	2.200
September 14	−1.050	.74	1.790	May 10	−1.225	1.34	2.565
September 28	−1.000	.61	1.610	May 24	−2.000	.16	2.160
October 12	− .950	.51	1.460	June 7	−2.000	1.08	3.080
October 26	+ .075	1.89	1.815	June 21	− .150	3.61	3.760
November 9	−1.200	....	1.200	July 5	+ .925	3.02	2.095
				Total	....	32.89	34.405

In 1900–1901 the evaporation exceeded the rainfall by 8.655 inches, while for the same period in 1901–2 the evaporation exceeded rainfall by but 1.515 inches. The distribution of rainfall throughout the

growing season the past year was also quite even. The only period when a serious deficiency of soil moisture occurred was in April and May, and thus the lack of water for the perennial crops under experiment, viz, asparagus, blackberries, raspberries, gooseberries, and currants, was not so apparent as in previous years. Water was applied and the records were carefully kept, but since practically no gain in yield of crops was found, they were recorded for future use rather than for publication this year. The conditions of rainfall and evaporation at Vineland were not far different from those recorded for New Brunswick.

THE USE OF PUMPS FOR IRRIGATION IN HAWAII.

By Jared G. Smith,

Special Agent in Charge Hawaiian Experiment Station.

With the exception of the island of Kauai, Hawaii has almost no large rivers. What running streams there are on the islands are on the rainy side, and here the mountain slopes are usually cut into deep, narrow, precipitous gorges separated by knife-blade ridges.

The cultivation of sugar on the windward side of each of the islands is usually not dependent upon irrigation. Large quantities of water are required, but the water is used for fluming the cane to the mill and not for growing crops.

The principal sugar-producing areas are on the more level lands on the dry side of the islands; and the lands which have proven most productive, yielding the phenomenal large crops of sugar which have made the Hawaiian Islands famous, are in an almost waterless region, not only where there are no running streams, but where the annual rainfall is very light.

Without exception, on all of the islands where there are extensive cultivated areas the slope of the lands from the mountain to sea is very abrupt. The average rise on the entire northeastern coast of the island of Hawaii averages approximately 500 feet to the mile, and this is equally characteristic of Oahu and Maui. With such abrupt slopes, the construction of storage reservoirs is not practicable except in the most favored localities.

The rainfall of the islands depends almost entirely on the relative elevation of the land and its situation as regards the principal mountains. While there is in a general way a rainy and a dry season, these seasons are not very sharply marked. But, as a general rule, on all of the islands of the group a larger proportion of the rainfall comes between the first of October and the last of March. The northern, northeastern, and eastern coasts of the islands constitute the rainy districts, owing to the fact that the northeast trades blow with little intermission during fully ten months in the year. In the remaining two months there are periods of calm, or periods when occasional great storms sweep in from the south. General rains, as distinguished from local showers, are characteristic of these south or Kona storms.

As stated before, the most productive sugar lands are on the dry side of each of the islands. This is especially true on Oahu and Maui. Oahu alone produces, on its five great plantations, fully one-third of

the sugar grown in the group. It is in the dry districts that the highest yield of sugar per acre is obtained. These yields are rendered possible, first, because of the superior fertility of the soil on the dry side of the island, as opposed to the soils on the wet side of the islands; and also because of the immense irrigation plants which have been constructed and which are maintained as an insurance by the plantation companies. The pumping of water for irrigation has reached its highest development in the Hawaiian Islands.

With the exception of a single body of water upon the summit of Mauna Loa, at an elevation of over 14,000 feet, there are no great natural lakes other than lagoons anywhere in the islands. There are no natural surface reservoirs from which water can be obtained above the level at which it is required on either the rainy or dry side of the islands.

The streams carry comparatively little water at their heads. The presence or absence of streams depends entirely on the structure of the land and upon its formation. The islands are all volcanic and have been formed by numberless successions of eruptions throwing out molten lava, or mud, or volcanic sand. There is no uniformity of structure, either as between the different islands of the group, or as between the different portions of the same island. That water can be obtained in one location is no sign that it can be obtained in another locality where the surface conditions appear to be similar.

In the development of the present system of irrigation in these islands vast sums of money have been expended, and even now but little is known in regard to the location of many of the principal underground streams. But, as a general rule, an abundant supply of artesian, fresh, or moderately brackish water may be obtained by sinking wells along the coast. From experimental work in the development of underground water on the islands of Maui and Oahu it would seem to be the general rule that water is also obtainable in sufficient quantity for irrigation wherever a volcanic flow of one age overlaps the volcanic flow of a much greater age. The geological development of these islands is from northwest to southeast. The oldest islands are at the northwestern extremity of the group, and on each island, without exception, the mountains or volcanic peaks at the northwestern extremity of the island are of an older geologic period than that toward the southeast; and so, wherever the mountain masses of the newer age overlap the older masses underground streams of water can be developed.

On the island Maui the mountains back of Lahaina are older than Mount Haleakala, which constitutes East Maui. The extensive tunnels and underground workings made on Kihei plantation, which lies at the eastern base of Mount Haleakala, have developed an enormous stream of underground water at a point where the lava flow, appar-

ently coming from Mount Haleakala, overlaps the bed rock of a much older age which probably found its origin in the Wailuku Mountains of West Maui.

On Oahu similar streams of underground water of immense volume are being developed by underground workings on Oahu plantation, apparently where the lava flows from the more recent Koolau Mountain chain overlaps the geologically older Waianae formation.

To irrigate the land on the dry side of the islands, only two methods are practicable. Either the water must be pumped from great depths, or irrigation ditches must bring the water around from the wet side of the island to the dry side. A number of such irrigation ditches, some of them of great capacity and length, have been constructed; but from the slope of the land, the nature of the soil, and its configuration, its deep gorges and high narrow ridges, the construction of these ditches is extremely costly. So, wherever it is possible to obtain underground water in sufficient quantity and of sufficient purity for irrigation this latter method is found to be the best.

It is a characteristic of sugar cane that it requires a maximum amount of water during the hottest and driest summer months, and the yield of sugar depends very largely upon the quantity of water which can be applied during that period.

With irrigation it is possible to obtain average yields of 10 or more tons of sugar per acre on the richest lands on the leeward side of Oahu, where without irrigation yields of less than half of that would be obtained.

On Oahu it is not possible to get water from the mountain streams in large quantity, although the rainfall in the Koolau Range is as high perhaps as any other location in the group, approximating in some seasons 200 inches per annum, and equaling the highest annual rainfall obtained in the Hilo district on Hawaii.

This Koolau Range is a very broken one, with impenetrable gorges and ridges covered with a tangled forest. Although the islands have been occupied by white men for over eighty years, there are still portions of these mountains which have not been penetrated by the explorer. Here, as in other rainy districts on the other islands, the most of the streams flow toward the northeast coast. One of these, which debouches onto the plains, separating the Koolau Mountains from the Waianae, has recently been tapped at its upper waters by an irrigation ditch which carried the flow to the Wahiawa colony and the Waialua plantation. But, as on Hawaii and Maui, the greater portion of the water which falls in this mountain range must go to waste. Yet this forest-covered Koolau Mountain range has a direct influence upon the underground water supply of the region which separates it from the Waianae Mountains, and a continuation of the present abundant supply of underground water for the Oahu, Ewa, and

Honolulu plantations depends almost absolutely upon the preservation of the forests upon these mountains.

In the pumping of underground water to be used for irrigation, pumps of four different types are in use—the centrifugal pump, the multivalvular pump, the direct-acting plunger pump, and the automatic valvular pump. The centrifugal pump is used where large quantities of water are to be lifted comparatively short distances. The direct-acting plunger pump has been used experimentally in wells from 100 to 300 feet in depth. There are only a few of either of these types in the islands, and without exception they have proven to be exceedingly expensive in their operations and entirely unsuited to modern requirements.

Fully 95 per cent of the pumps used for securing irrigation water are of the multivalvular and automatic-valvular types, and because of their economy the latter are rapidly superseding all other forms. Practically all of the large pumping plants which have been installed within the last three years have been pumps with mechanically automatic valves.

Complete data relative to the cost of raising water have been secured from a number of plantations, and, in addition to the statistics here submitted, complete reports concerning the pumping operations of several of the larger plantations will be supplied at the end of the present year.

On the island of Oahu there are five large plantations, and these produce about one-third of the sugar grown in the Hawaiian Islands. These plantations are all on the leeward or dry side of the island, and every one of them is absolutely dependent upon underground sources of water for its supply.

On Oahu plantation 4,950 acres of land are under irrigation, and the average yield of cane for this entire area is 10 tons per acre. The plantation lies mainly at an elevation of over 200 feet above sea level, extending from this elevation up to about 750 feet. There are eight pumping stations, having a daily capacity of 54,250,000 gallons, lifted to an average height of 452 feet. The source of the water is forty 12-inch artesian wells, the water rising in these wells to about sea level. Three of these wells are 350 feet in depth; twenty average 420 feet in depth; seven, 600 feet in depth; ten, 800 feet in depth. Four Riedler pumps are in operation, and two of the same make are in process of construction; these pumps are of the automatic, mechanical-valvular type.

The other two pumping plants are the Worthington, of the multivalvular type. The approximate cost of the six pumping plants already in operation has been $711,000, or $143.63 per acre irrigated.

Pumps Nos. 1 and 2, Riedler fly-wheel pumps, with a daily capacity of 10,250,000 gallons, are in operation, respectively ten and eleven

months in the year. The water is lifted to a height of 370 feet, at a cost of $175 per day for each plant, or at an average cost of 23 cents per million gallons of water lifted 1 foot.

Pump No. 3, also a Riedler pump, has a daily capacity of 8,000,000 gallons, lifted 155 feet. The average daily cost of operation is $75, or 6 cents per million foot-gallons.

Pumping station No. 4, a Worthington pump, has a capacity of 8,000,000 gallons, lifted to the height of 560 feet, at an approximate cost of $225 per day, or 41 cents per million foot-gallons.

Pump No. 5, a Riedler, lifts 11,000,000 gallons per day to the height of 560 feet, at a cost of about $325 per day, or 50 cents per million foot-gallons.

Pump No. 8, a Worthington, lifts 5,000,000 gallons of water 100 feet, at a cost of $80 per day, or 16 cents per million foot-gallons.

Pumps Nos. 6 and 7 are not as yet completed. They are both Riedlers, and will each lift 6,000,000 gallons of water daily to the extreme height of 750 feet.

Ewa plantation lies to the west and bordering Oahu plantation, but extends from sea level to a height not to exceed 200 feet above sea level. The production of sugar per acre is higher on this plantation than on any other in the world. There are nine pumping plants, of a total daily capacity of 71,600,000 gallons.

There are in use at the present time three Riedler compound pumping engines, with Corliss engine and fly wheels, of a capacity of 10,000,000 gallons each per twenty-four hours. The extreme height to which these pumps can lift water is 200, 150, and 50 feet, respectively.

One Riedler triple-expansion pump, with Corliss engine and fly wheel, having a capacity of 10,000,000 gallons in twenty-four hours, with an extreme lift of 210 feet.

Two Blake compound pumping engines, with Corliss engines and fly wheels, with a capacity of 9,000,000 gallons each per twenty-four hours; the extreme height that the water is lifted is 170 and 150 feet, respectively.

One Blake compound pumping engine, with Corliss engine and fly wheel, having a capacity of 2,500,000 gallons per twenty-four hours, lifted to a height of 80 feet.

Two Riedler compound pumping engines, with Corliss engine and fly wheels, have a capacity of 2,000,000 gallons each per twenty-four hours, lifted to a height of 75 feet.

One Blake duplex pump, driven by a single-cylinder Atlas engine, with a capacity of 2,000,000 gallons per twenty-four hours, lifted to a height of 75 feet.

The total capacity of these pumps aggregates 66,500,000 gallons per twenty-four hours, the discrepancy between these figures and those given above being due to the pumps in operation to supply the mill

and the flowing wells. The maximum capacity of the pumps is required only during the three dry summer months—June, July, and August.

The pumping stations on Ewa plantation have cost for installation \$534,504.01, \$513,677.68 of this amount having been invested in the machinery and \$20,826.33 in buildings. This makes the cost \$172.85 per acre.

During the year 1901, 2,971.45 acres of sugar were irrigated, at a cost of \$35.72 per acre for both plant and rattoon cane; the total production of this area was 32,370.875 tons of sugar. There were in 1901 approximately 6,750 acres under cultivation. There were 3,014.95 acres of land harvested in 1901, yielding an average of 10.89 tons of sugar per acre, or a total of 32,832.81 tons, valued at \$1,979,008.62 net at the plantation.

Ewa plantation has twenty-two 10-inch wells and thirty-two 12-inch wells, ranging in depth from 310 to 605 feet. These are all artesian wells, the water rising to from 22.01 to 26.04 feet above sea level.

The daily report for pumping stations Nos. 1 to 7, inclusive, for April 27, 1902, is appended, and also the monthly report for March, 1902.

Daily report of pumps on Ewa plantation, April 27, 1902.

	Pump No. 1.	Pump No. 2.	Pump No. 3.	Pump No. 4.	Pump No. 5.	Pump No. 6.	Pump No. 7.
Hours run	8	8	2	2	24	24	1
Steam pressure	130	90	80	80	120	120	180
Revolutions	68	50	23	22	68	69	72
Pounds coal used	3,000	1,200	1,080	1,080	1,600	18,530	3,250
Head in feet	48	79	90	90	109	190	150
Feet of suction	16	19	20	20	12	12	2
Gallons water pumped	2,387,082	731,142	375,000	456,258	881,286	10,500,421	487,312
Foot-pounds duty	43,307,216	36,612,000	35,009,600	39,972,828	56,751,776	73,702,592	86,650,932

Monthly report of pumps on Ewa plantation, March, 1902.

No. of pump.	Capacity.	Speed.	Hours run.	Coal per hour.	Water per hour.	Horsepower.	Coal per horsepower.	Water per horsepower.	Water per pound of coal.	Average head.	Average suction.	Water in wells.	Total water pumped.	Total coal consumed.
				Lbs.	Gallons.		Lbs.	Gals.	Lbs.	Feet.	Gal.	Gal.	Gallons.	Lbs.
1	10,000,000	73, 68, 54	270	393	397,847	145	2.7	2,744	1,012	48	15.6	56	107,418,790	106,250
2	3,000 000	50	130	171	121,857	40	4.3	3,016	712	75.5	19	166	15,841,410	22,700
3	7,000,000	23	57	623	187,500	81	7.7	2,315	301	93	20	129	10,687,500	35,495
4	9,000,000	22	102	595	228,125	148	4.0	1,541	383	93	20	129	23,268,750	60,705
5	10,000,000	68, 65, 60	233	592	440,643	299	2.0	1,474	744	105	11	65	102,669,819	137,905
6	10,000,000	69, 64, 58	225	861	437,591	428	2.0	1,022	500	185	11	65	98,457,975	193,895
7	11,000,000	73, 68, 54	236	937	489,372	436	2.1	1,123	522	145	2	17	115,491,792	221,250
8	Flow well.	65	120	61	68,160	......	......	....	114	11.5	2	10	8,179,200	7,100
9	2,500,000	66	77	176	104,157	37	5.3	....	491	56	1	50	8,020,089	13,864

On the island of Maui there are two groups of plantations, each depending to a greater or less extent upon pumps to supply water for irrigation, the group of small plantations back of Lahaina on West Maui and the group of four large plantations occupying the foot of the entire western slope of Mount Haleakala from Haiku to Kihei.

Very interesting data was secured in regard to the pumping operations of the Hawaiian Commercial and Sugar Company. This information, prepared by Mr. J. N. S. Williams, chief engineer of this company, follows:

The following is a monthly report for the pumping plants on this plantation:

Pump No. 1.

Hours run	400
Revolutions	960,000
Water delivered ... gallons	76,800,000
Coal consumed ... tons	119
Height of delivery ... feet	100

Water is delivered through approximately 2,500 feet of 4-inch pipe. The engine in this case is a compound condensing engine, having cylinders 16 and 32 inches in diameter, with a 36-inch stroke, coupled direct to double-acting plunger pumps, plungers 13 inches in diameter when new; steam pressure, 100 pounds. The valve gear is an old style poppet, variable by hand.

Coal per million gallons lifted 1 foot high, 31 pounds.

Pump No. 2.

Hours run	48
Revolutions	172,800
Water delivered ... gallons	5,000,000
Coal consumed ... tons	12
Height of delivery ... feet	57

This is a centrifugal pump driven by a 16 by 32 foot slide-valve engine, and is very wasteful.

Coal per million gallons lifted 1 foot high, 84 pounds.

Pump No. 3.

Hours run	240
Revolutions	720,000
Water delivered ... gallons	57,600,000
Coal consumed ... tons	40
Height of delivery ... feet	95

This engine is a compound condensing slide valve having cylinders 16 and 32 inches in diameter, with a 36-inch stroke coupled direct to double-acting plunger pumps, having plungers 13 inches in diameter when new. This engine is governed by an ordinary governor. Steam is furnished by ordinary horizontal tubular boilers at 90 pounds per square inch, and it does fairly good work.

Coal per million gallons lifted 1 foot high, 14.6 pounds.

Pump No. 4.

Hours run	180
Revolutions	286,422
Water delivered ... gallons	33,439,769
Coal consumed ... tons	38
Height of delivery ... feet	200

This engine is a compound condensing Corliss having cylinders 24 and 32 inches in diameter, with a 42-inch stroke, coupled direct to double-acting plunger pumps, having plungers 12 inches in diameter when new, fitted with the Riedler automatic gear on the suction and discharge valves. It delivers water through a 30-inch pipe about 3,000 feet long.

Coal per million gallons lifted 1 foot high, 11.37 pounds.

Pumps Nos. 5 and 6.

	No. 5.	No. 6.
Hours run	370	404
Revolutions	1,092,574	1,272,038
Gallons delivered	127,538,021	148,510,436
Coal consumed ... tons	140	154
Height of delivery ... feet	300	300

The engines are triple expansion, having cylinders 19, 33, and 50 inches in diameter, with 42-inch stroke, coupled direct to double-acting plunger pumps fitted with Riedler valve gear on the suction and discharge valves, and delivering the water through 24-inch pipes about 6,000 feet long. These engines are served by Sederholm boilers of the multi-tubular type and furnish steam at 180 pounds pressure. The boiler plant is fitted with a Green economizer in the flue, and every improvement that the best modern practice dictates has been applied in this plant.

Coal consumption per million gallons lifted 1 foot high, 7.1 pounds.

I would say that the heads of delivery are calculated from the average pressure given on the gages on the pressure pipe, plus the vacuum shown on the gages on the suction pipes, as is usual in calculating heads of pumping engines. This, then, will include the friction head on the machine. We have on these plants adopted the method of figuring our coal per million foot-gallons for the reason that it gives us a figure readily comparable between one pump and another, while if we adopted the coal per horsepower we should find ourselves in difficulties in correctly estimating the work done by each pump, on account of the differences in horsepower developed by some makes of pumps as against others. This calculation is performed as follows: The total number of gallons delivered is multiplied by the height of delivery, and millions and parts thus obtained, divided into the total coal used, in pounds, gives us the figure which you will find.

The price of coal, delivered at the pumps on this plantation, averages in the vicinity of $12 per ton.

It will be seen here that in every case the pumps fitted with the Riedler automatic valves are much more economical in their consumption of coal, per million foot-gallons, than any other pumps in use on this plantation.

Kihei plantation lies directly south of the Hawaiian Commercial and Sugar Company's plantation. The steps which have been taken to develop water on this plantation are extremely interesting, in that not only have wells been sunk, but extensive shafts and tunnels have been constructed to develop a sufficient amount of water.

In one of these shafts two pumps are located at a depth of 300 feet from the surface, the boilers which supply them with steam being located on the surface at the mouth of the shaft. This pumping station has one Risdon pump and one Riedler. As on practically all the plantations of the Hawaiian Islands the Riedler pumps, provided

with automatic valves, have proved to be far superior in every way to pumps of the multivalvular type, such as the Worthington and the Risdon.

The following record of two Worthington pumps on this plantation for the week ending January 18, 1902, is given below:

Boiler room.

Coal, average per day .... pounds..	21,000
Steam, pounds per square inch	165
Feed water .... degrees..	160
Boilers in use	3

Engine No. 1.

Duty	High.
Vacuum	26
Total revolutions	151,590
Revolutions per minute	31
Head, in feet	220
Total gallons pumped (pump displacement)	20,204,915
Total hours run	81½
Average hours per day (six days)	13⅗

Engine No. 2.

Duty	High.
Vacuum	23
Total revolutions	66,240
Revolutions per minute	32
Head, in feet	160
Total gallons pumped (pump displacement)	8,828,467
Total hours run	34½
Average hours per day (three days)	11½
Distiller .... hours..	22

The cost of operating amounts to over 22 cents per million foot-gallons, whereas the most economical Riedler pump on the adjoining Hawaiian Commercial and Sugar Company's plantation lifts water at a cost of less than 4 cents per million foot-gallons, with coal at an average price of $12 per ton.

On Kihei a battery of direct-acting plunger pumps, such as are used in the oil regions of Pennsylvania, have been installed and given a thorough trial, but have now been discarded because of the extravagant expenditure of coal.

On Kihei plantation the total daily pumping capacity is 26,500,000 gallons. This is supplied by two Worthingtons, each with a capacity of 6,000,000 gallons, one Risdon with a capacity of 7,500 gallons, and one Riedler with a capacity of 10,000,000 gallons. The cost of the Worthington pumps is $142,347.59; of the Risdon pump, including the three boilers, $180,207.96; and of the Riedler pump, including one boiler, $78,456.87.

The Worthington lifts the water to a height of 350 feet; the Risdon, 450 feet; and the Riedler, 350 feet.

To the north of the Hawaiian Commercial and Sugar Company's plantation lies Paia plantation. There are two pumping stations on this plantation. Station No. 1 has one Riedler high lift, with cross compound Corliss engine. This was erected in 1898. Its capacity is 5,500,000 gallons per twenty-four hours, lifted to a height of 425 feet. There is also a Riedler low-lift pump, with the same kind of engines, with a capacity of 4,500,000 gallons lifted to a height of 210 feet. The total average consumption of coal at pumping station No. 1 is 14.045 tons per day.

Pumping station No. 2 contains one Blake pump, with a capacity of 1,000,000 gallons per twenty-four hours, lifted to a height of 70 feet. This pump, when running in January, 1902, lifting water to a height of 20 feet, required an average of 3,150 pounds of coal per day.

At Paia plantation the average annual rainfall ranges from 26 to 29 inches. On the Hawaiian Commercial and Sugar Company's plantation it ranges from 20 to 25 inches, while at Kihei it never rains except during occasional periods when storms come in on the Kona or southern coast.

The northernmost plantation of this group is that of the Haiku Sugar Company. This plantation is on the borderland between the wet and the dry portions of the island of Maui, and the rainfall varies much in accordance with the elevation.

At 300 feet above sea level the average rainfall is about 50 inches per annum; at 1,200 feet it amounts to over 60 inches, and farther back toward the mountains, from 5 to 6 miles from the ocean on the northern coast of the island, the rainfall amounts to over 100 inches per annum.

This plantation, in common with others of the group, derives a portion of its water supply from irrigation ditches built to tap the headwaters of the stream flowing through the rainy belt on the northern slope of Mount Haleakala.

This plantation has only two pumps, and these are used for only five or six months in the year. Both of these pumps are duplex double-acting Riedlers, driven by horizontal cross compound Corliss condensing engines; one lifts 4,000,000 gallons per twenty-four hours to the 250-foot level, and the other 5,500,000 gallons to the height of 450 feet.

The amount of water required for irrigating an acre of sugar cane varies according to the soil and the location of the land, whether on the dry or on the wet side of the island. As a general rule, a supply of 1,000,000 gallons per twenty-four hours will irrigate from 80 to 100 acres, depending entirely upon the soil.

The amount of water used is ordinarily estimated at so many men's water per day. "One man's water will irrigate about 7 acres per day, and cane is watered every six to twelve days." On the island of Maui the land requires irrigation every six to eight days; on the island of Oahu the period ranges from eight to ten or twelve days. One laborer can distribute water over about three-fourths of an acre of cane in one working day.

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